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Plastics

Dealing with the Manufacture, Uses and Potentialities of Plastic Materials

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NOTICES

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SAVE PAPER

More than ever is paper waste required for our war industries. Waste paper makes munitions in a hundred forms—from shell cases to aeroplane parts.

The fact that goods made of raw materials in short supply because of war conditions are advertised in this journal should not be taken as an indication that they are necessarily available for export.

EDITORIALS

Education in Industry

WE are, it is conceded, a first-class industrial nation. How this has happened—by genius, national character, sheer accident and other reasons—we need not consider here. It is certain that if we wish to retain that status among nations that are striving hard to surpass us technically we must so organize our youth, our future industrial workers and leaders, in ways different from those we now employ. It is upon our educational system, general and technical, that our whole future industrial framework depends—and our educational system, in so far as it is preparatory to the factory and workshop, is lamentably weak.

There is surely something wrong in a State in which, although some 500,000 children are put through the elementary educational mill annually, only a small fraction undergo any sort of secondary education and most of these end up as civil servants, bank clerks and the other hosts of "black-coated" workers. The remainder are allowed to enter industry with but a modicum of general knowledge, almost invariably ignorant of industry and its needs, and it is left to industry to train them from the beginning. Little wonder is it, then, that the new entrant or apprentice undergoes, during his first year, the doubtfully elevating privilege of fetching the beer or tea. It is not until the second year that he is left with, let us say, a file in his hand to work out his future salvation.

It is of the greatest satisfaction, therefore, that with all its teething troubles the youthful plastics industry should so early in its career lay down the principle that its future is bound up with the standard of education of those that enter it, and, what is more, the industry itself must aid that youth to reach the necessary high standard.

At the annual lunch of the Institute of the Plastics Industry, on October 28, its chairman, Mr. Kenneth Chance, told us of the latest developments to this end and of the important sums of money that had been raised to give our hopes practical effect. It is to his untiring efforts in this respect, from the inception of the Institute, that we owe this enviable condition, for Mr. Chance has always regarded the plastics industry, indeed any industry, as being conditioned by the type of worker that entered it. His insistence on good design in plastics and on the fact that a good plastics designer must know what plastics are and what moulding means, has already lifted high the standard of plastic goods.

The principal guest at this lunch was, most appropriately, the President of the Board of Education, Mr. R. A. Butler. "The leaders of plastics," he said, "are pioneers, both in developing a new and ingenious amalgam of progress and in the manner in which they are fusing the two worlds of training and factory practice.

"Here is an activity which is ready to combine with its virtues as a pioneer concern the release of its young people for continued education," he said. "Those who enter industry want not only skill in training and design, but also the wider training which can be more profitably undertaken as the young workers grow in experience and life."

Mr. Butler congratulated the Institute on setting aside some £20,000 as a fund for educational and training schemes. These should provide for a more modern and up-to-date system of apprenticeship and secure competent recruits.

It was probable that future training for industry would be achieved by a combination of facilities which the industry could itself offer and the use of the technical colleges.

In the case of the plastics industry the art schools would also come into their own since this was an industry which

was particularly dependent upon good design. Mr. Butler hoped that the educational fund now being set up would be used not only for scholarships and prizes but also for establishing research programmes at technical colleges in connection with plastics on the lines of the practice being followed at the present moment in the U.S.A. There was no industry in which research was of more importance.

Synthetic Rubbers

IF there is one scientific subject that has received more publicity, good and bad, than any other, since Pearl Harbour, it must surely be that of the so-called synthetic rubbers. If there is a publicist who is capable of clearing up the fog that envelopes this problem it is surely Dr. H. Barron, the well-known plastics technologist, who, in addition to his broadcasts on the radio on plastics, has been pressing the readers of the "Evening Standard" for some years now to consider synthetic rubber as a factor in our future welfare.

He has just written a book under the title of "Modern Synthetic Rubbers" and we need not point out how timely is its appearance. It is not a treatise for the man in the street, for it is a technical book. Yet Dr. Barron's style of writing is extremely readable, and there are two chapters—the first a general one on "Natural Rubber and Synthetic Materials" and, the second, "Economics of Synthetic Elastic Materials"—which can be read by all industrialists. By those erstwhile kings of the rubber plantations, who refused to regard synthetic rubber seriously, it can be read with interest, if not pleasure.

The search for new elastic materials resembling rubber was not only due to the thirst for knowledge and the desire to improve on rubber. Perhaps the greatest incentive was that of rabid nationalism or the desire to safeguard future supplies. Natural rubber itself can be improved and, as the author contends: ". . . the oil resistance of rubber could be made satisfactory provided that really large-scale fundamental research were attempted . . . it would have removed the chief raison d'être of synthetic rubber." It is, indeed, paradoxically fortunate for the United Nations that this discovery had not been made, for there would have been little or no incentive in the U.S.A. to produce synthetic rubber while Germany did so as a preparation for war.

In his chapter on the economics of the industry, Barron gives some remarkable figures. In 1938 Russia produced some 53,000 tons of various types of synthetic rubber. By 1940, Germany made 60,000 tons and U.S.A. about 12,000 tons in 1941. He adds that recent American schemes involve the production of 400,000 tons per annum (a recent issue of this journal gave 745,000 as the figure). The problem of the future of this remarkable industry, vis-à-vis the return to natural rubber and its improvement, is one of the most intriguing we shall have to face.

In a special chapter the author tackles the vexed problem of nomenclature, since the word rubber no longer means one material. It seems likely that chemists and physicists will refer to elastomers, thioplasts and the like. Some of these names have nothing to commend them euphonistically, but, obviously, some system of nomenclature is very necessary.

The chief part of the book deals with the raw materials, the methods of manufacture (polymerization, co-polymerization and emulsion polymerization) and the technology of synthetic elastics. It is all admirably done and the study of some 30 types made by eight different countries is as deep as it is comprehensive. To say that Dr. Barron has rendered good service to science in general is not enough. He has not only clarified what we have called "the science of big molecules," but he has, scientically and economically, more clearly than most writers, correlated the rubber, synthetic rubber and modern plastics industry into one coherent whole.

"Modern Synthetic Rubbers," by Dr. H. Barron. Published by Chapman and Hall, Ltd. Price 25s. net.

Valves in Polyvinyl Chloride

Continuing from the October Issue of this Journal an Account of the Evolution of Plastic Valves for Chemical Plant in Germany. Stress is laid on Simplification of Form and Economy in the Material and Production Time

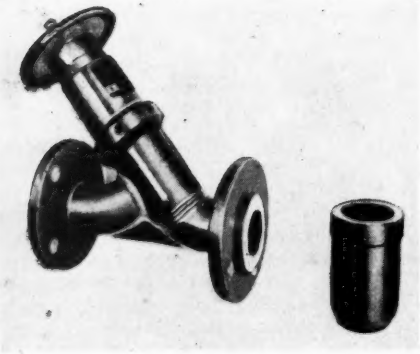


Fig. 16 (above).—Early form of slanting-type valve constructed and assembled principally by welding and having valve screw cover of entirely closed form (enlarged view of cover seen at right).

IN the first part of his account, Klant (" Kunststoffe," 1942/32/41) described how the modern valve for chemical plant in polyvinyl chloride had developed from a prototype produced by machining from solid blocks through intermediate forms fabricated by the cementing together of various tubular sections to structurally simple forms involving the welding of single thicknesses of tube which, in certain cases, was integral with a pipeline of which the valve formed a part.

Fig. 17 (above).—Later form of inclined-type valve produced by welding from polyvinyl chloride tube, showing open form of spindle cover. In contrast to the type shown in Fig. 16, this pattern is more accessible and economizes in raw material.

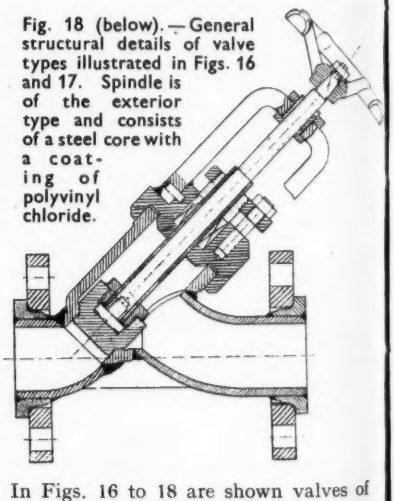


Fig. 18 (below).—General structural details of valve types illustrated in Figs. 16 and 17. Spindle is of the exterior type and consists of a steel core with a coating of polyvinyl chloride.

In Figs. 16 to 18 are shown valves of such construction that the easy workability of Vinidur between temperatures of 130 and 150 degrees C. may advantageously be utilized. The valve body is hot pressed from 8-mm. thick sheet and assembled by welding. The

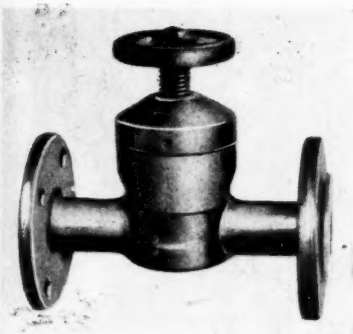


Fig. 19 (above).—Diaphragm valve of earlier type constructed in polyvinyl chloride. This type has been replaced by the welded construction shown in Fig. 20.

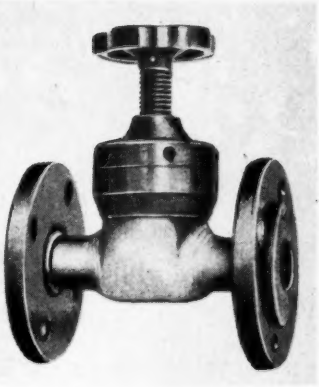


Fig. 20 (right).—Modern form of plastic valve of diaphragm type. Many early difficulties encountered with stuffing-box-type valves were obviated by the use of this system.

steel core and which is welded to the Vinidur protecting tube to give a fluid-tight joint. The spindle nut is in brass.

The upper part of the valve structure is formed out of plate material suitably bent and welded, the complete component being, in turn, again joined by welding to the stuffing box of the valve, which is machined from a solid block.

In the design according to Figs. 17 and 18, the common closed form of support is replaced by an arc plugged in and welded to the stuffing box. In this way access to the stuffing box is made easier. However, this type of construction still possesses certain weaknesses, the strength of the arc being fundamentally insufficient to act as a satisfactory support for the spindle. The support may, without any difficulty, be developed directly as a moulded component

seat and the upper strengthening sleeve for the screw-down are also pressed on. Inlet and outlet supports for the valve body are bent up from standard tubes and are welded into the housing; they are provided with suitable fixings to take loose plastic flanges. To stiffen the whole assembly the input and output pipes are provided with a welded-on rim.

Unlike any of the valves previously described, this type is provided with an external spindle, the lower portion of which, coming into contact with the fluids handled by the valve, is provided with a Vinidur tube shrunk on to the steel core (Fig. 18). The valve head in hard Vinidur is screwed to the spindle, but is capable of rotating. Its upper part bears against a headed Vinidur screw which engages with the

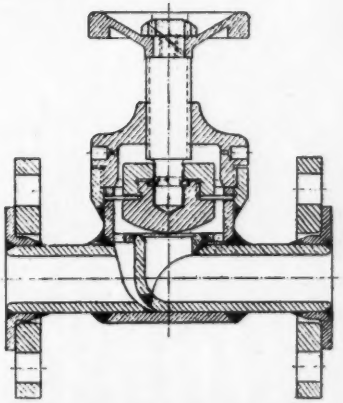


Fig. 21.—Structural details of the diaphragm valves illustrated in Figs. 19 and 20. The flexible diaphragm in this case is in soft Igelite, Buna, or natural rubber. Welding is extensively used.

which should exhibit greater strength than the Vinidur component, but should also possess extreme resistance to corrosion. This phase in the evolution of valve design, however, is not yet completed.

Valves Without Stuffing Boxes

In conclusion, reference will be made to valves possessing no stuffing boxes. These are illustrated in Figs. 19 to 21. Whilst originally the body of the valve was constructed exclusively of machined components screwed or jointed together by means of adhesives (Fig. 19), hot working and welding techniques have now displaced the earlier method.

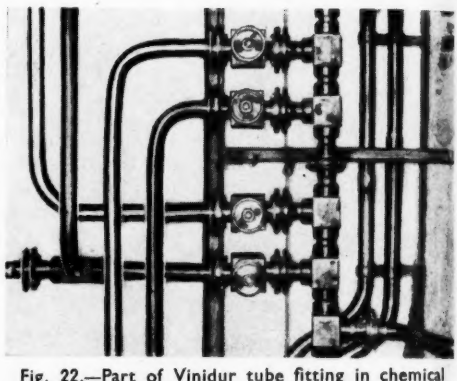


Fig. 22.—Part of Vinidur tube fitting in chemical plant showing incorporation on plastic valves of old block type.

In contrast to valves provided with stuffing boxes, sealing between the body of the valve and the screw spigot is achieved by means of a flexible, corrosion-resistant membrane consisting of soft Igelit, Buna or natural rubber. An advantage of this method of construction is that packing difficulties are automatically eliminated.

The lower part of the valve, like those previously described, consists of a hot-formed and

Fig. 23.—View of large tube battery in polyvinyl chloride handling hydrochloric acid. Particular attention should be given to the tube junctures and to the size of the battery as revealed by comparison with the iron ladder shown at the right of the illustration. Polyvinyl chloride valves are extensively used in units of this type.

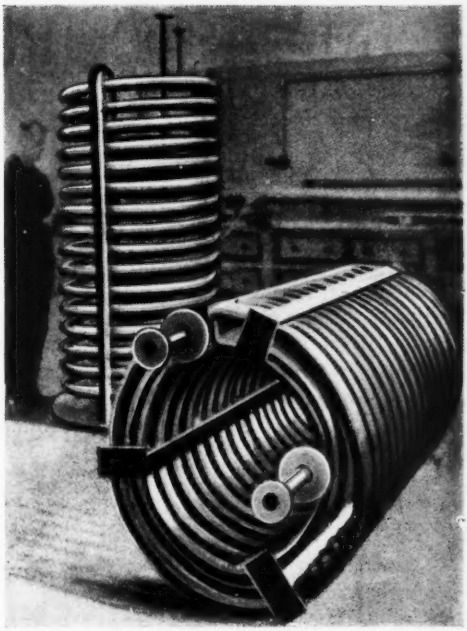


Fig. 24.—Single and double cooling coils constructed by welding in polyvinyl chloride tube. Integral with components of this type may be used valves of modern design constructed and assembled by welding from the same resin. The size of the coils may be judged from the height of the operator seen at the left of the illustration.

welded Vinidur tube assembly, the upper part being formed from turned and welded sheet joined, in turn, to the lower part by welding. The rising pipe carrying the flexible membrane is also welded on.

The foregoing notes adequately show the extent to which vinyl chloride plastics are being adopted in Germany. The obvious first outlet is in the chemical industry, where not only resistance to acid but complete absence of metal is wholly to be desired; often mechanical strength is not of the first importance.

Soft Rubber-like Plastics from Cellulose

It has been the practice and the aim of the plastics industry, generally speaking, to provide rigid structures out of the raw material it makes. This is as true for the cellulose derivatives as for the phenolic and urea formaldehyde resins. To-day there is an incentive to produce softer, rubber-like compounds from even these substances. The subject is dealt with, so far as cellulose derivatives are concerned, in an article by D. R. Wiggam in the August issue of "Rubber Age."

The wider range of usefulness of "soft" plastics has been largely overlooked except in a few instances such as the use of nitrocellulose in artificial leather. Nevertheless it is true that cellulose derivatives, such as ethyl cellulose, may be compounded with chemical and oil plasticizers (e.g., castor oil) to yield compositions having many of the qualities which have made rubber applicable in such a wide variety of uses. These compositions can be made soft yet tough, pliable and flexible.

The cellulose derivatives can be formulated to yield products having some qualities equal to or even superior to those of rubber compositions. For example, formulations have been made with abrasion resistance several times greater than that of two rubber samples tested.

Their degree of elongation is limited, however, when compared to rubber; and on the same basis of comparison, their "bounce" is low.

Water resistance comparable to that of compounded rubbers can be built into these soft plastics. They can be made to show good pliability at low temperatures. For example, at a temperature where rubbers were stiff, boardy and brittle, the soft plastics were still pliable and tough.

Good chemical resistance is readily obtained. Two rubbers used for comparison purposes became brittle after only seven minutes' exposure in a stream of air containing 3 per cent. ozone. Some of the cellulose plastics were not brittle and appeared unaffected after 96 hours' exposure to the same concentration of ozone.

D

FILLERS FOR PLASTICS

(Continued)

Previous issues of this article, which began in our August number, dealt with the compositions and functions of wood flour, cotton and silk, asbestos, mica and other mineral fillers and pigments. With this issue the author brings to a conclusion his authoritative views of the role fillers play in the scheme of plastics formulation and construction. There is little need to stress the importance of clarifying the various effects these fillers exert on the main resinous structure, and the value not only to users, but to the plastics industry itself, of the final comparisons tabulated and graphed in this issue

By E. E. HALLS

General Discussion on Influence of Fillers

IT has been stressed that the purpose of the filler is to render the plastic base generally suitable or manipulable through fabrication processes and to impart best characteristics for specific applications—that is, strength, electrical quality, stability, heat resistance, etc. The modification in this specific direction has to be achieved without deterioration in other respects. However, expectations must not be allowed to extend beyond the capabilities of the filler. The functions and possibilities of the latter are generally established and known to a close degree of accuracy. On the other hand, a number of other factors are operative, each capable of variation over a wide margin, yet susceptible to control. In consequence, those concerned will find it necessary to do some experimental work to ensure that every factor is best suited to obtain maximum advantage from the filler in question. This additional research work in individual cases is an essential corrolary in order to amplify the general statements made in these notes.

Selection and Variables

It has already been indicated that the filler itself can be selected from a range of qualities, that alternatives exist for its mode of incorporation, and that the proportion of it may be adjusted over wide limits. For any class of plastic, the base resin may be varied somewhat, e.g., phenolics may be phenol, cresol, furfural or other condensation products; or they may be high or low flow. Other ingredients may be present, for example, plasticizers with cellulose products. Again, moulding methods may differ with respect to tool, injection or pressure, and temperature or removal from the tool. These are typical of numerous variables. Hence, a user must not take a specific success as the basis of a more wide exploitation of a formulation without checking all the facts in relation to the newer fields. Again, applying with equal force is the fact that test values and characteristics given by

Table 20.—Comparative Characteristics for Moulded Phenolics having Different Fillers.

	Type of Filler						
	Normal wood filled	Chopped cotton cloth, large pieces	Shredded cotton cloth	Cotton linters	Mica	Asbestos	Mineral powder for heat resistance
Mechanical values:							
Impact strength, BSS 771, ft./lb.	0.20	1.0	0.75	0.35	0.20	0.10	0.20
Cross breaking strength, tons/sq. in.	5.0	6.0	5.0	4.5	4.0	3.0	3.0
Tensile strength, tons/sq. in. ..	3.0	3.0	3.0	3.0	3.0	2.0	2.0
Crushing strength, tons/sq. in. ..	15.0	14.0	14.0	16.0	10.0	8.0	10.0
Physical values:							
Specific gravity	1.35	1.35	1.35	1.35	1.66	2.0	1.70
Water absorption (24 hrs.), % ..	0.3	0.5	0.5	0.4	0.1	0.1	0.1
Approx. max. safe temperature, °C.	135	135	135	135	150	160	160
Electrical values:							
Power factor at 800 cycles, % ..	Up to 40	Up to 40	Up to 30	Up to 30	.3	15	15
Electric strength at 20°C., volts/mil. AC	200	150	150	200	300	200	180
Electric strength at 90°C., volts/mil. AC	50	25	25	50	250	150	100
Permittivity	8.0	8.0	8.0	8.0	6.0	10	15
Volume resistivity at 20°C, ohms/cm. cube	10^{12}	10^{10}	10^{11}	10^{11}	10^{13}	10^{12}	10^{11}

a product from one source will not necessarily hold good for a closely similar product from a different source. This point casts no aspersions upon the plastics industry, but is merely the result of differing techniques developed independently over a period of time. In consequence, users should purchase to specification whenever practicable, the specification being a British Standard if available, or alternatively, one containing the essentials with reasonable limits to test values, omitting reference to characteristics that do not apply. Again, the same factor demands broadmindedness in assimilating all test values that are quoted.

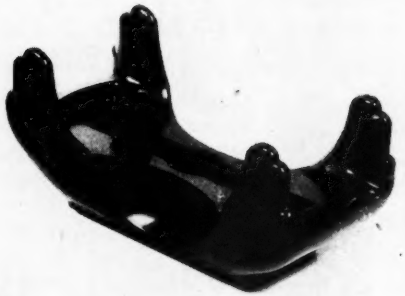
Correlation of Properties

Bearing all these points in mind, Table No. 20 has been compiled for phenolic mouldings having different fillers. It broadly correlates for the different mouldings, mechanical, physical and electrical properties. It refers to the general-purposes wood flour filled moulding, three types of shock resisting product having coarse and fine cotton cloth and linters as filler, mica filling for optimum electrical characteristics, asbestos filling for resistance to heat or burning, and mineral powder filling of the clay or siliceous earth variety for stability under fluctuating heat. Actual values for each characteristic can vary widely and the figures quoted have been chosen to be indicative and comparative.

Shock-resisting Properties

Wood-filled phenolic mouldings are of good mechanical strength for all ordinary purposes. The impact strength values given in Table No. 20 show that chopped cotton cloth in large pieces (e.g., of the order of 1 sq. cm. area) improves this quality about 400 per cent., shredded cloth by about 300 per cent., and cotton linters by 100 per cent. Figs. 7A and 7B show photographically two telephone set mouldings which for normal work are produced in ordinary wood flour filled phenolic powders. The vulnerable portions of these articles are the grid of the mouthpiece and the corner projections of the cradle. Shock-resisting moulding powders, therefore, are very valuable for these components for heavy-duty service, but a coarse cotton cloth material is useless because it would not fill the grid nor the prominences of

Figs. 7a and 7b.—Two telephone set mouldings in wood-filled phenolic resin.



the two parts respectively: it would be baffled in the mould, the resin only filtering past to these critical portions. The cotton linter filled material would be satisfactory, give much improved impact, and good appearance. The shredded cloth filled material would yield even better impact values but with some slight reduction in appearance quality due to a mottle effect. Again, the coarser the textile filling, rather greater the difficulty in moulding, although this statement is entirely relative and no insuperable troubles arise. Shrinkages are a little different for the different powders, and tools must be designed accordingly, or, if changing from wood to cotton filled, attention must be given to any resultant dimensions that are critical in order to establish if tool modifications are involved. Mica and other mineral powders do not reduce impact values, but asbestos decreases it to about one half. Cross breaking, tensile and crushing strengths are lower for all the mineral fillers. The mineral fillers markedly increase specific gravity but appreciably reduce water absorption; they also improve considerably the safe operating temperature, namely, that which can be maintained without serious loss of strength, distortion or blistering. The mineral fillers also improve electrical characteristics, especially power factor and electric strength under hot conditions. The mica-filled mouldings have special claims for low power factor. Fig. 8 is a photograph of a valve base, simple in form but critical with respect to electrical properties and stability. The mica-filled moulding powders, pre-dried, suit this purpose, giving high electric strength and low power factor. Also, the component not only has to withstand the heat of the basing operation whereby it is cemented to the glass valve, but also to withstand tropical temperatures and humidities without increase in

Fig. 8.—Mica-filled valve base.

external diameter or distortion because of entering a seating. The mica-loaded materials, mineral content 40 to 60 per cent., are eminently suited to this purpose.

In small assemblies, particularly in automatic electric apparatus such as lighting units, relays, and the like, stability of dimensions under service conditions of varying humidities and temperatures, is rather vital. The phenolic plastics are much superior in this respect to the other two main groups of synthetics, the aminos and the cellulose acetates. Fillers have some influence upon this, and examples have been selected from tests on moulded products to demonstrate the comparison between phenolic resins with various fillers, using a cast phenolic resin as the basis of comparison. Stability is recorded by changes in weights and in dimensions taken at intervals under exaggerated conditions. The latter included the following:—

(a) Complete immersion in distilled water at ordinary temperature.

(b) Exposure to a cycle of conditions embodying a warm, dry day period (55/60 degrees C., 65/75% humidity) and a cool, moist night (18/22 degrees C., 100% humidity with condensation).

(c) Continuous dry heat at 70 degrees C.

(d) Continuous dry heat at 110 degrees C.

The results are briefly summarized in Tables Nos. 21 to 26. Dimensions are referred to in length (L), width (W) and thickness (T). The materials covered by these data are as under:—

Table No. 21.—Cast phenolic resin as a basis for comparison.

Table No. 22.—An ordinary high-quality wood flour filled moulding powder.

Table No. 23.—Paper-filled mouldings, showing also a mineral content of 10 per cent.

Table No. 24.—A wood flour filled material containing also 8 per cent. of mineral loading.

Table No. 25.—A heavily mineral-loaded material, mineral content 33 per cent.

Table No. 26.—A heavily mica-loaded material, containing 60 per cent. mica.

The tables are self-explanatory, but as data of this type are a little difficult

Table 21.—Stability Test Data on Cast Phenolic Resin.

(Specific gravity, 1.34; normal material of amber or other colours.)

Test conditions	Change in:	Period of test days		
		1	7	21
Complete immersion in distilled water at 20°C.	Gain in weight, %	0.10	0.50	1.30
	Increase in dimensions, % L	Negligible	"0.10	0.30
	Increase in dimensions, % W	Negligible	0.10	0.35
	Increase in dimensions, % T	Negligible	0.60	1.35
Cyclic warm and cold humidity conditions	Change in weight, %	−0.10	−0.25	−0.40
	Change in dimensions, % L	Negligible	−0.10	−0.25
	Change in dimensions, % W	Negligible	−0.07	−0.19
	Change in dimensions, % T	Negligible	Nil	−0.10
Continuous dry heat at 70°C.	Loss in weight, %	1.3	2.9	4.3
	Decrease in dimensions, % L	0.50	1.0	1.4
	Decrease in dimensions, % W	0.54	0.83	1.5
	Decrease in dimensions, % T	0.28	0.85	1.2
Continuous dry heat at 110°C.	Loss in weight, %	2.4	6.3	8.7
	Decrease in dimensions, % L	0.90	2.1	2.7
	Decrease in dimensions, % W	0.90	2.0	2.6
	Decrease in dimensions, % T	0.50	1.5	2.5

Table 22.—Stability Test Data on Wood Flour Filled Phenolic Mouldings.
(Specific gravity, 1.31; no mineral loading or pigmentation.)

Test conditions	Change in:	Period of test days		
		1	7	21
Complete immersion in distilled water at 20°C.	Gain in weight, %	0.24	0.82	2.0
	Increase in dimensions, % L	Nil	0.06	0.42
	Increase in dimensions, % W	Nil	0.12	0.50
	Increase in dimensions, % T	Nil	0.16	0.45
Cyclic warm and cold humidity conditions	Change in weight, %	+0.05	+0.17	+0.80
	Change in dimensions, % L	Negligible	Negligible	Vary from +0.33 to −0.25
	Change in dimensions, % W	Negligible	Negligible	
	Change in dimensions, % T	Negligible	Negligible	
Continuous dry heat at 70°C.	Loss in weight, %	0.54	1.36	2.36
	Decrease in dimensions, % L	0.10	0.20	0.36
	Decrease in dimensions, % W	0.15	0.25	0.42
	Decrease in dimensions, % T	0.20	0.41	0.61
Continuous dry heat at 110°C.	Loss in weight, %	0.85	3.15	3.95
	Decrease in dimensions, % L	0.50	0.72	0.84
	Decrease in dimensions, % W	0.65	0.80	0.95
	Decrease in dimensions, % T	0.45	0.63	1.00

Table 23.—Stability Test Data on Paper-filled Phenolic Mouldings.
(Specific gravity, 1.58; mineral loading, 10.0%.)

Test conditions	Change in:	Period of test days		
		1	7	21
Complete immersion in distilled water at 20°C.	Gain in weight, %	1.05	3.6	4.8
	Increase in dimensions, % L	1.10	1.85	2.10
	Increase in dimensions, % W	0.50	1.00	1.45
	Increase in dimensions, % T	0.95	4.10	5.53
Cyclic warm and cold humidity conditions	Change in weight, %	+0.10	+0.54	+1.5
	Change in dimensions, % L	Fluctuating changes, varying from +0.10 to +0.70		
	Change in dimensions, % W			
	Change in dimensions, % T			
Continuous dry heat at 70°C.	Loss in weight, %	2.05	3.1	4.0
	Decrease in dimensions, % L	0.70	0.86	1.0
	Decrease in dimensions, % W	0.20	0.31	0.45
	Decrease in dimensions, % T	0.32	0.45	0.82
Continuous dry heat at 110°C.	Loss in weight, %	3.0	4.5	5.0
	Decrease in dimensions, % L	1.36	1.45	1.75
	Decrease in dimensions, % W	0.36	0.55	0.60
	Decrease in dimensions, % T	1.00	1.05	1.85

to assimilate from a mass of figures, they have been represented graphically in Figs. 9 to 13, and a brief criticism of these is given below.

Fig 9 shows the progress of water absorption of these materials over extended periods. The wood-filled material and the wood filler, together with a little mineral loading, are closely similar and about 50 per cent. more absorptive than the cast resin. The 33 per cent. mineral-loaded material is approximately the same as the cast resin, while the 60 per cent. mica-filled material is outstandingly superior to all. The paper-filled product lies in the other direction, relatively very absorptive. The corresponding dimensional changes are recorded in Fig. 12, and, bearing in mind the difficulties of measuring these, particularly in the small thickness direction, they can be said to agree very well with the weight changes. Thus the paper-filled material is markedly the least stable, the mica material most stable, and the others, of similar order to one another,

Table 24.—Stability Test Data on Wood Flour/Mineral Filled Phenolic Mouldings.
(Specific gravity, 1.46. Mineral loading, 8.0%.)

Test conditions	Change in:	Period of test days		
		1	7	21
Complete immersion in distilled water at 20°C.	Gain in weight, %	0.30	0.85	2.05
	Increase in dimensions, % L	Nil	Nil	0.31
	Increase in dimensions, % W	Nil	Nil	0.20
	Increase in dimensions, % T	Nil	Nil	0.14
Cyclic warm and cold humidity conditions	Change in weight, %	+0.19	+0.46	+0.70
	Change in dimensions, % L, W, T	Negligible, maximum average value ±0.05		
Continuous dry heat at 70°C.	Loss in weight, %	0.60	1.54	2.90
	Decrease in dimensions, % L	0.10	0.27	0.35
	Decrease in dimensions, % W	0.20	0.45	0.73
	Decrease in dimensions, % T	0.05	0.19	0.38
Continuous dry heat at 110°C.	Loss in weight, %	0.80	2.75	3.70
	Decrease in dimensions, % L	0.45	0.68	0.81
	Decrease in dimensions, % W	0.50	0.73	1.0
	Decrease in dimensions, % T	0.10	0.25	0.60

Table 25.—Stability Test Data on Mineral Loaded Phenolic Mouldings.
(Specific gravity, 1.75; mineral loading, 33.0%.)

Test conditions	Change in:	Period of test in days		
		1	7	21
Complete immersion in distilled water at 20°C.	Gain in weight, %	0.12	0.67	1.5
	Increase in dimensions, % L	0.02	0.20	0.55
	Increase in dimensions, % W	0.05	0.38	0.84
	Increase in dimensions, % T	0.10	0.40	0.53
Cyclic warm and cold humidity conditions	Change in weight, %	−0.01	−0.01	−0.17
	Change in dimensions, % L, W, T	Fluctuating increases and decreases, negligible amount, maximum average value ±0.05		
Continuous dry heat at 70°C.	Loss in weight, %	0.36	0.94	1.56
	Decrease in dimensions, % L	0.10	0.31	0.55
	Decrease in dimensions, % W	0.16	0.40	0.53
	Decrease in dimensions, % T	0.04	0.08	0.36
Continuous dry heat at 110°C.	Loss in weight, %	0.52	2.7	3.09
	Decrease in dimensions, % L	0.58	0.95	1.00
	Decrease in dimensions, % W	0.70	0.86	0.93
	Decrease in dimensions, % T	0.24	0.68	1.12

NOTE.—(1) All values are percentages of original value. (2) L=length, W=width, T=thickness.

lie intermediately. The small though definite fluctuations in weight under cyclic warm and cold humidity conditions have not been plotted, but Fig. 12 gives a picture of the limits of fluctuation with respect to dimensions. These, again, clearly place the materials into categories as aforementioned.

Figs. 10 and 11 show the weight losses at 70 degrees C. and at 110 degrees C. Except that the cast phenolic fails to withstand the temperature as well as might have been expected, and has joined the paper-filled material in the extreme position of the graph, the ranking of the materials is again approximately the same, that is, 33 per cent. mineral filler somewhat superior to wood or wood plus a small percentage of mineral loading, and heavy mica loading outstandingly good. Fig. 13 shows the dimensional shrinkages, with, again, much the same rating.

Before leaving the question of stability in dimension and shape, a more rapid form of testing may be

mentioned, as it is very effective in discriminating between various groups of phenolic mouldings, which, after all said and done, are an exceptionally stable group. This test comprises steaming followed by baking. For tubular and cylindrical articles, blistering and distortion can be checked by ring gauges, and dimensional movement from four marked diameters, two at right angles to each end of the specimen. Average results on half a dozen specimens can be taken as a sound evaluation. The actual steaming test comprises suspension of the specimens in steam at 100 degrees C. in a jacketed heater. Measurements of expansion are taken. The baking then follows, comprising half an hour dry heat at 160 degrees C. Measurements are again taken. It will be noted that the test is a very rigorous one, being a forced, hot expansion, ensuring entry to all absorbent pores, followed rapidly by a high-temperature bake to drive absorbed steam out again. Table No. 27 summarizes test results.

Table 26.—Stability Test Data on Mica Filled Phenolic Moulding.
(Specific gravity, 1.80. Mineral loading, 60.7%.)

Test Conditions	Change in:	Period of test days		
		1	7	21
Complete immersion in distilled water at 20°C.	Gain in weight, %	0.10	0.35	0.50
	Increase in dimensions, % L	Negligible	Negligible	Negligible
	Increase in dimensions, % W	Negligible	Negligible	Negligible
	Increase in dimensions, % T	Negligible	Negligible	Negligible
Cyclic warm and cold humidity conditions	Change in weight, %	Negligible	Negligible	Negligible
	Change in dimensions, % L	Negligible	Negligible	Negligible
	Change in dimensions, % W	Negligible	Negligible	Negligible
	Change in dimensions, % T	Negligible	Negligible	Negligible
Continuous dry heat a 70°C.	Loss in weight, %	0.24	0.62	1.03
	Decrease in dimensions, % L	0.10	0.33	0.45
	Decrease in dimensions, % W	0.04	0.14	0.20
	Decrease in dimensions, % T	0.10	0.14	0.28
Continuous dry heat at 110°C.	Loss in weight, %	0.38	1.8	2.04
	Decrease in dimensions, % L	0.20	0.65	0.90
	Decrease in dimensions, % W	0.05	0.10	0.30
	Decrease in dimensions, % T	0.15	0.29	0.46

Table 27.—Stability Test Data on Mineral Filled Phenolic Mouldings, Cylindrical Section.
Subjected to 8 hours in steam at 100°C. followed by ½ hour at 160°C.

Sample No.	Type	Specific gravity at 20°C.	Mineral filler %	Change in diameter from original of 1½ ins. in thousandths of an inch						Remarks
				After steam test			After steam and heat test			
				Max.	Min.	Average	Max.	Min.	Average	
1	Wood filled	1.34	Nil	+56	+35	+43	+7	−3	+2	—
2	Mineral filled	1.61	39.6	+ 6	+ 1	+ 2.5	−5	+1	−2	—
3	Mineral filled	1.68	46.5	+ 4	− 1	+ 1	+2	−1	+1	—
4	Mineral filled	1.67	46.2	+ 4	+ 0.5	+ 3	−5	+2	−2	—
5	Mineral filled	1.66	39.5	+ 4	+ 1	+ 3	−5	0	−2	—
6	Mineral filled	1.62	39.6	+10	+ 1	+ 4	−5	Nil	−2	Some blistering
7	Mineral filled	1.66	43.5	+ 4	+ 2	+ 2.5	−4	+2	−0.5	Very uniform
8	Mineral filled	1.66	44.0	+ 4	+ 1	+ 2.5	−4	+4	−0.5	Very uniform

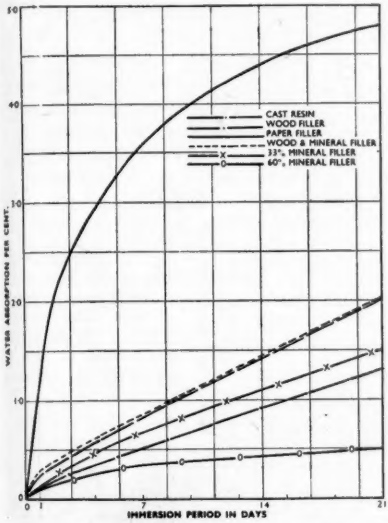


Fig. 9.—Water absorption at 20°C.

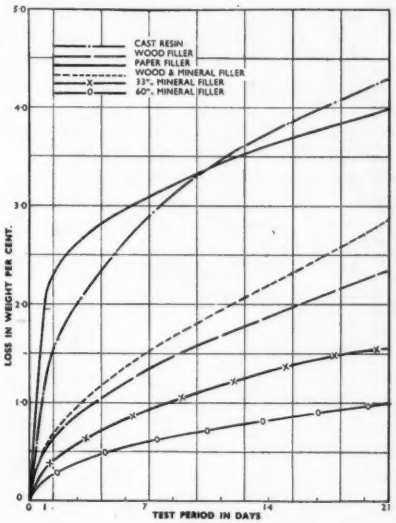


Fig. 10.—Dry heat loss at 70°C.

Sample No. 1 in this is an ordinary wood-filled material of good quality. Its changes under the test are reasonably uniform, amounting to an average of 4½ per cent. under the expanded (steam) conditions, and returning closely to original dimensions after baking (within an average of 0.2 per cent.). The remaining samples of mineral-filled mouldings from different sources are very good indeed; in fact, they are virtually stable under both sets of conditions.

Taking an overall view of the statements so far given under general comments, there is no doubt that proper choice of textile filler gives higher impact values in phenolics to suit specific needs; that micaceous filling in high percentage dictates better electrical characteristics; and that a high percentage of mineral filling provides for dimensional stability under damp or hot conditions. It must be borne in mind that the mineral fillers cause more abrasion on moulding tools and attention to retention of dimensions must be greater. Likewise, drills and taps have shorter life and should be chromium plated.

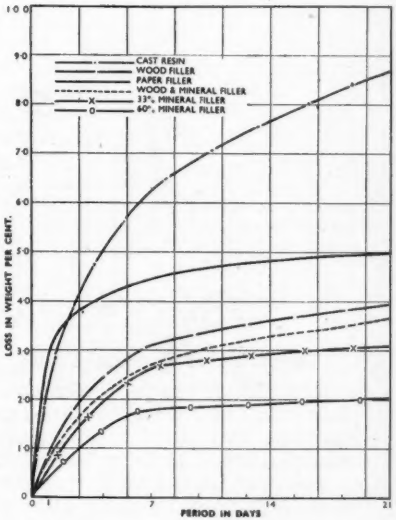


Fig. 11.—Dry heat loss at 110°C.

E

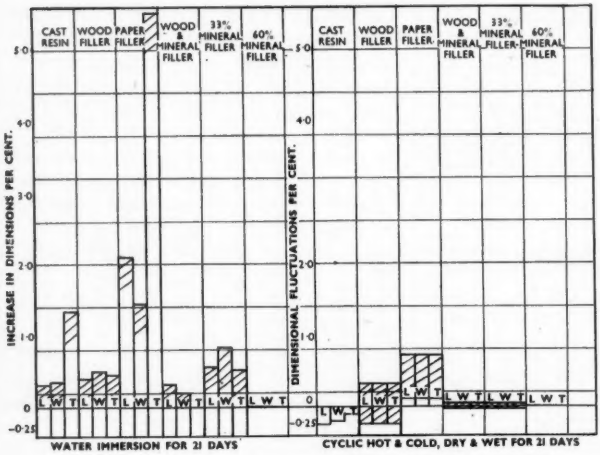

CAST RESIN
WOOD FILLER
PAPER FILLER
WOOD & MINERAL FILLER
33% MINERAL FILLER
60% MINERAL FILLER
INCREASE IN DIMENSIONS PER CENT.
DIMENSIONAL FLUCTUATIONS PER CENT.
WATER IMMERSION FOR 21 DAYS
CYCLIC HOT & COLD, DRY & WET FOR 21 DAYS

Fig. 12.—Dimensional changes in phenolic mouldings containing various fillers, exposed to water immersion or cyclic humidity conditions.

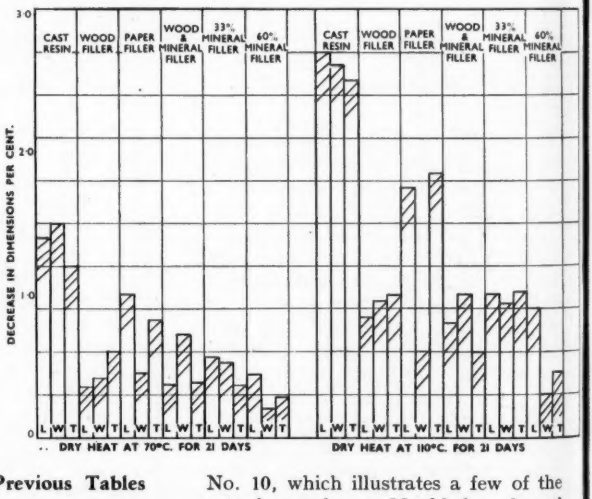


Fig. 13.—Decrease in dimensions of phenolic mouldings containing various fillers exposed to dry heat.

Discussion of Previous Tables

Returning now to the earlier tables, Nos. 2 to 9, these are compiled from test data on typical mouldings, with special reference to fillers, but including other characteristics to give some idea of what may be expected in these respects. Table No. 2 shows that of the mineral fillers, the clays, micas, silica earths, asbestos, lithopone, aluminium oxide, iron oxide are all used in phenolic moulding powders. Further illustration of this is seen in No. 10, which illustrates a few of the actual powders. Moulded rod and sheet material almost invariably use wood flour as filler and are harder, tougher, lower in water absorption and more dimensionally stable than moulded articles. Natural brown and black are the colours usually available, the black generally employing carbon-black colorant. They are Continental products, and insufficient attention has so far been afforded to their manufacture in this country.

There is no reason why any of the other fillers should not be incorporated in these forms. A number of sheet materials are now appearing in which the filler comprises wood or paper pulp instead of the standard wood meal. These materials have greater impact strength, but are somewhat more absorptive, but a little more easily drilled, tapped and otherwise machined.

Table No. 3 shows that the amino mouldings, sheet and tube, use aluminium and zinc oxides, silica earths, ultramarine and lithopone as typical fillers, all in conjunction with cellulose filling in the form of paper or wood meal. No higher impact flock filled or heat resisting high percentage mineral filled materials appear to have been developed. From the dimensional movement viewpoint, even the 25 per cent. filled material (sample No. 11) showed no outstanding difference from any of the other compositions tested. A high mica content material would certainly be of interest to electrical engineers, if developed.

Table No. 4 shows that in the thermoplastics colours are produced with or without appreciable mineral matter and that the extent of mineral filling normally encountered causes little improvement, if any, in dimensional stability under service conditions, resistance to dampness or to heat. Incidentally, Fig. 14 is of a typical tiny coil bobbin for which cellulose acetate is employed. It is found that if high mineral matter is incorporated in the acetate powder for such thin-walled and fragile configurations, there is a tendency to brittleness and fracture in service. The incorporation of cellulose (wood meal) in thermoplasts is the exception rather than the rule. It raises the melting point as before discussed. (See sample No. 6.) Table No. 11 refers to thermoplastic powders.

Of the thermoplastic materials, cellulose acetate has been the most important in recent years. Sheet, rod and tube material is similar with respect to pigmentation to the mouldings. Benzyl cellulose is little used except for special purposes. Nitro cellulose base plastics use similar fillers to the acetates; the polyvinyls, not yet developed to the full, are tending to use similar loading pigments. The methacrylates and polystyrols have not yet extended beyond the colouring stage to call for attention. However, from the practical point of view, there seems to be no restriction to the use of any of the fillers enumerated. It is worthy of note that researches are in progress on special fillers for the polystyrols. These have as their purpose the discovery of fillers appropriate to the unique electrical characteristics of polystyrol, especially low loss at high frequencies. The object of the filler is fundamentally to improve resistance to temperature and so better enable the polystyrols to replace high-frequency ceramics. The possibilities of ignited aluminium oxide, titanium oxide and berylium oxide are being explored.

The soft rubbers (Table No. 5) use zinc oxide, siliceous earths, chalk and the like for reducing compressibility

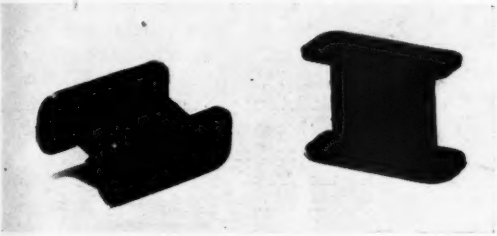


Fig. 14.—Small coil bobbin made of cellulose acetate. The extremely thin walls need special considerations.

and increasing hardness. Iron oxide and antimony sulphide are used additionally as colourants. A range of synthetic rubbers is included in the table. Regarding the hard rubbers or loaded ebonites, Table No. 6 is mainly self-explanatory with respect to the purpose of loading. Mineral loading is extensively used to improve rigidity at elevated temperatures, and whereas 60 degrees C. is regarded as the maximum safe temperature for a straight ebonite, 90 degrees C. is safe for a 50 per cent. mineral-loaded material.

A hard, heavily mineral-loaded vulcanized rubber composition intended for use in the form of panels and bars in electrical applications revealed:—

Total rubber content ...	17.0%
Sulphur (combined with rubber)	6.2%
Sulphur (free)	0.1%
Bitumen	3.8%
Siliceous earth	70.0%
Resins (acetone soluble)	2.9%

Table No. 7 refers to casein-base materials of different origin, and zinc oxide will be noted as the principal loading material. Table No. 8 shows china clay typical of the shellac mouldings, and Table No. 9 that clay, barytes and asbestos are common to the bitumen plastics.

In the foregoing, much has been said upon fillers for plastics, although, perhaps, more has been omitted. The subject is a vast one, space is limited, as also must be an individual's experiences and outlook. But likewise is research and industrial work so far completed, vast though this may be. The future, therefore, holds much—new plastics, new fillers, new combinations of both and wide fields for exploitation as yet unexplored. Each plastic base will be a well-defined product; and so must each filler fulfil all the requirements of exacting specifications.

ITALIAN PLASTIC CONTAINER

A reader has sent us the two photographs shown below, which are of a captured Italian shell container now in his possession. He states that the material employed appears to be phenolic resin-impregnated chopped fabric (a variety of colours is noted), and that the moulding is the longest draw he has ever seen.

There are three parts—the tubular container proper, cover and holding ring. An interesting point is the eccentric form of the annular head.

The length of the draw can be estimated from the photograph by comparison with the ordinary match-box included for the purpose. The overall length is about 21 ins.

World's Industry Employs Plastics

ELECTRICAL

Insulating coatings for metals, fabrics and compositions may be provided with a new synthetic resin base medium "Resiflex" (David C. Brown Co.). The coating requires baking after application, and, in the hardened state, is resistant to hot oils, salt spray and a wide range of temperature variations. It possesses high breakdown strength and a low power factor. On a clean metallic surface, one coating (thickness unspecified) may be safely used up to a pressure of 500 volts. Resiflex solution is supplied in a low-viscosity form and is water clear. Baking temperature is 275-350 degrees F. for 6-30 mins., depending upon the size of unit and type of material treated. **Permissible working temperatures for plastics** were investigated by Nitsche and Dober, and reported in "Electrotechn. Zeit," 1942/63/280. The authors point out that the maximum temperature to which commercial plastics may safely be heated has not been generally determined. For the designer of electrical installations, such data are of the utmost importance. In the tests, permissible maximum temperature for short-time heating was defined as that temperature which a material can withstand for 200 hours and show not more than 10 per cent. deterioration in bending and impact strength after it has cooled down again to room temperature. Furthermore, linear shrinkage must not exceed more than 0.6 per cent. Some 16 samples were tested by the investigators and are tabulated in their report. Standard test pieces were stored for 200 hours at different temperatures in such a way that they tended to deflect under their own weight. After cooling for 18 hours, bend strength, impact strength and shrinkage were determined. The results of the investigations may be summarized as follow:—Older moulding materials, such as lead borate with mica fillers, and cement or waterglass with suitable inorganic fillers, withstand prolonged exposure to temperatures as high as 250-300 degrees C. Cold moulding materials consisting of certain resins or bitumen with asbestos and other organic fillers may safely be used for short periods up to 180 degrees C. without any marked loss in strength or with any dimensional variation. Hot moulding materials of the bitumen type have, somewhat surprisingly, been found safe for short-period use up to 80 degrees C. Of other plastics only acetyl cellulose failed at temperatures as low as 30 to 60 degrees C. Type of failure varies markedly with resin composition, but commonly takes the form of bending cracks or blow holes. For all types of resin tested, safe, maximum working temperatures lie far below charring point, and mechanical failure of the types described cannot be considered as contributing directly to electrical breakdown.

GENERAL ENGINEERING

High-pressure sleeve bearings of special construction are described in Italian patent 381,836, granted to Deutsche Versuchsanstalt für Luftfahrt. The bearings are so designed that the outer working layers contain a

(Continued on p. 408.)

PLASTICS IN ASSEMBLED BU

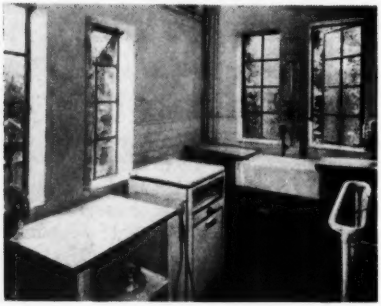


Fig. 1 (left).—Specimen modern kitchen. (With acknowledgments to "Studio Year Book," 1942.)

I.—THE "MINIMUM" KITCHEN

Suggestions for the prefabrication of what must be considered the hub of the home

Fig. 2.—Built-in cupboard by L. K

AFTER the war we shall need between three and four million new kitchens for new buildings, as well as for houses and flats which will have to be brought up to date. According to statistical predictions,[1] the number of new homes to be erected has been estimated as 2,716,000, and this figure contains 750,000 for slum clearance alone. Assuming that more than half of the population is likely to live in homes comprising not more than two-three people, the importance of the smaller dwelling units, such as small houses and flats, becomes more real than ever before.

It is much more difficult to build and furnish good kitchens than good-looking reception-rooms or bedrooms, mainly because of the lack of co-ordination between the various components and units which have to be assembled on the site on a relatively small space. There is no need to enumerate the endless variety of site operations involved in the construction of kitchens, in spite of the fact that a great number of well-designed prefabricated components, such as cookers, sinks, refrigerators, etc., are available.

Such machinery units, however well designed, will not produce automatically kitchens of high efficiency. The units seen in the illustration (Fig. 1) are products of high technical standard, well designed and well made. But one cannot

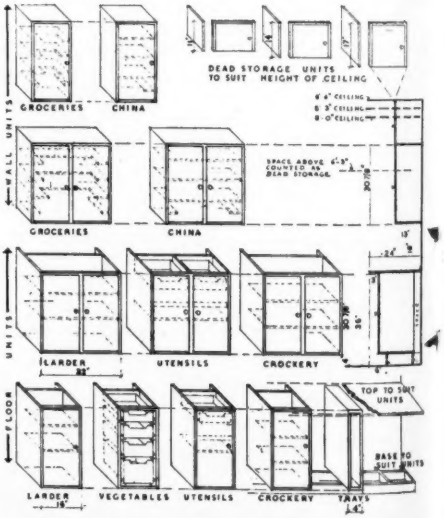
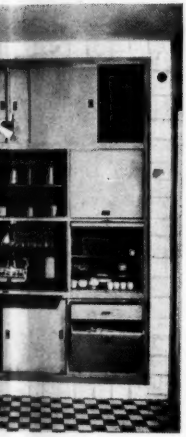


Fig. 3.—Standards for cabinets by the Association for Planning. (With acknowledgments to the "Architects' Journal.")

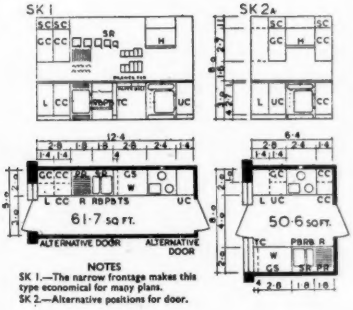
D BUILDING STRUCTURES



upboard by L. Kozma.

Fig. 5 (right).—Example of "marketed" kitchen.

By
G. FEJÉR



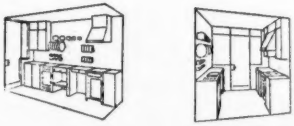


Fig. 4.—Two variations of kitchen layout. (With acknowledgments to the "Architects' Journal.")

help feeling that the housewife must spend quite a bit of time in cleaning corners which are so difficult to get at but which collect every bit of available dust and dirt. There is some tiling and a few (inevitable) pipes in the corner, the arrangement of which is somewhat unfortunate.

One cannot blame the architects whenever a kitchen is not as "streamlined" as a modern car. We must not forget that architects have to struggle with a legion of contractors, workers on the spot, manufacturers, and clients simultaneously. No wonder that it is generally the housewife who is the inarticulate loser in this "Battle of Crafts." Sometimes architects are not consulted at all, and the kitchen is the ultimate outcome of various purchases and site operations undertaken without any plan to co-ordinate the whole paraphernalia of equipment units.

There can be little doubt about the superiority of the workshop-made kitchen against the one built on the site, and there are many indications that we shall have kitchens which are factory-made to a larger extent than they are now. It seems to be the natural tendency of the development to regard the kitchen as one unit in which every component has its proper place predetermined by careful planning. This does not mean that every kitchen would have the same size, shape or

appearance; on the contrary, the more interchangeable components are being mass produced, the bigger the choice, and the wider the possibilities for individual variations in the final assembly.

By studying the various parts and components of kitchens, we find that many of these are already in standard types; others, again, can be standardized by further planning. Such work is being pursued by manufacturers, architects, committees, and various bodies concerned in producing better post-war living conditions, and a brief outline of this work is given in the chapter below. The plastics industry has contributed so far quite a number of equipment parts and the use of plastics will expand even more so soon as the prefabrication of kitchens becomes a reality. The writer has attempted to draw up a prefabrication scheme (see p. 403), analysing its aspects from the point of view of possible uses of plastics.

The supplementary use of plastics of equipment units normally made of steel, light metals, timber, asbestos-cement, copper, glass, china, etc., may not be quite as spectacular as some people visualize it, but the numbers involved in home markets (as well as abroad) make even the smallest items worth considering. With regard to large units, the fact that preassembled building units can be exported to those parts of the world where skill in assembly work is lower may have far-reaching economic consequences.

The Movement for Better Planning and Co-ordination

To plan better living conditions for the post-war world, various bodies and organizations are preparing plans and recommendations. As time goes on the number of these research groups increases and their activity takes more and more the shape of a nation-wide movement. The mere fact that manufacturers, architects, scientists, teachers, economists and individuals representing all walks of life are interested in post-war building rather indicates that planning is not a monopoly of any group of people, but everybody's business. It is often pointed out that there are too many such organizations already. On the other hand, every research group produces new ideas and collects valuable material as to the aims of the general public, thus making a contribution to the work undertaken by the M.O.W.P. Every step thus made to clarify technical and design possibilities and to make pre-assembly (or prefabrication) speedy and efficient brings us nearer to ideal solutions. As previously mentioned in these pages,[2] the provision of building components is not only necessary for peace-time considerations, but also for structures highly essential in wartime, for example, shipbuilding.

So far as our present problem is concerned, i.e., the planning of better kitchens, the planning work on hand is twofold:—

(a) Architectural planning to design well co-ordinated kitchens suitable for mass production.

(b) Manufacturers' planning and research to provide the technical basis for the mass production of components.

It is obvious that these two developments must go hand-in-hand to produce the best results.

(a) Architectural Planning

In the course of actual planning of kitchens for a group of houses or a block of flats, the architects have to make a number of decisions as to orientation as a whole, the relation of kitchens to dining-rooms (or dining recess), to choose the right surface treatments, floor covering, lighting, ventilation and to solve many similar problems of the general layout. Possibly the large majority of architects welcome standard components for store cupboards, vegetable racks, utensil cupboards, as such units relieve him of the doubtful pleasure of preparing detail plans and supervizing their execution. These units, however, must be well designed and available in standard sizes so that a certain amount of interchangeability is possible to suit various requirements.

Fig. 2 shows a built-in cupboard

designed by the prominent Continental architect, L. Kozma, and is a typical example of individual design where every detail is " made to measure " to suit the client. The writer remembers quite well (when working as an assistant to Mr. Kozma) that innumerable detailed plans had been drawn up for such built-in units until it was possible to reach the utmost simplicity of design, to rule out dust traps and to find the correct storing space for every tool and utensil needed. The architect's actual expenses in investigating such details over and over again are very high, and the costs of making such units must remain fairly high compared with mass-produced equipment.

Alternatively, there are many mass-produced joinery units on the market, but most of these, unfortunately, are fairly difficult to combine with other units such as cookers and refrigerators. Standard specifications to create better co-ordination are not known to the writer, as the only specification available on the subject deals with the details of kitchen cupboard fronts and dressers.[3]

In a report presented to the Ministry of Health, the Association for Planning and Regional Reconstruction has submitted plans in which standard dimensions have been carefully worked out. A reprint of the report has appeared in the technical Press,[4] giving a comprehensive analysis of the requirements of small and medium kitchens.

Fig. 3 shows a set of drawings prepared by the Association giving the measurements of the cabinets. These are suggested as mass-produced joinery types and would serve for storing all tools, utensils, as well as crockery. A ventilated cupboard for storing fresh food and a vegetable cupboard with tray-drawers are also suggested. All these dimensions appear to be extremely well considered, both from the point of view of co-ordination with cooker and sink units, and for storing of the articles for which they are intended. Several minute details of the sizes and shapes of crockery, utensils, etc., have been carefully investigated.

This report prepared by the Association for Planning and Regional Reconstruction is only concerned with the type of kitchen suitable for town dwellers, and all variations of suggested layouts are kitchens suitable for the preparation of meals only and not for laundering, heating, etc. The report contains nine different variations of the layout, three of which refer to combined solutions of kitchen and dining-rooms. Fig. 4 shows two of the variations of the smallest types.

The writer finds little to criticize in the basic principles of these plans, which will certainly disperse some misconceptions which exist on the subject of constructing kitchens. Instead of criticizing the few points which appear to be the weak spots of the plans, the writer has attempted to suggest certain modifications and a different approach to the construction on p. 402.

It must be understood that the Association's plans have been drawn up after consultations with the English Joinery Manufacturers Association only, and it is quite likely that, after more negotiations and collaborations with the other industrial societies, the plans will gradually reach a more advanced stage. Representatives of other industries are to be invited to co-operate.

(b) The Manufacturers' Planning

There are two ways in which manufacturers have approached the planning of better kitchens. First, there are the manufacturers who provide units of improved efficiency (such as refrigerators) and who specialize on the manufacture of such a unit only. The second group comprises manufacturers who produce a number of kitchen-equipment units such as cookers, tables, sinks, etc., and are capable of selling the whole kitchen as one unit. The two systems are, of course, complementary and, therefore, equally necessary. There are only very few firms capable of organizing the manufacture and sale of entire kitchen equipment so far. This system, however, is likely to produce better results for the public than the procedure of marketing parts of equipment by various manufac-

turers which are often difficult to co-ordinate.

In Figs. 5 and 6 are given two examples of kitchens which have been marketed by their makers, labelled with the manufacturers' " brand." We have chosen these two examples because of the contrast in character of the two firms: the one is a company specializing in joinery works, whilst the second is a well-known firm manufacturing electrical appliances as well as plastic mouldings and panels.

It can be readily seen that both kitchens, although very different in style

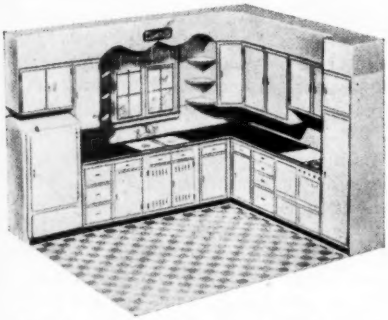


Fig. 6.—Second example of "marketed" kitchen.

and choice of materials used, have something in common, namely, there is more co-ordination between the units than in a kitchen which is pieced together in the more usual way.

The floor lines are clear, there are continuous skirtings instead of the usual awkward gaps which often occur left and right of cookers and refrigerators. In both cases the manufacturers have undoubtedly gone deep into every question which would improve the design and the choice of materials.

Both these kitchens are fairly large units, but, of course, there is no reason to believe why smaller kitchens could not be marketed in the same way.

It is quite possible that there will be more and more types of ready-to-use kitchens in the future, assembled, marketed and serviced by organizations specializing on such structures. The choice of available components in metals, wood and some plastic (or partly plastic) materials will be fairly wide, so that the best possible combinations can be achieved free from preconceived ideas.

Although the technical possibilities given by the various available materials are already very varied, it is likely that new types of sheet materials, alloys, glass products and plastics will become available for the constructors after the war.

Plastics in Kitchen Equipment

The number of plastic products which have been used so far as components of kitchen furniture may be regarded as small; these have, however, some interesting technical aspects for those who are actively engaged in developing post-war plans. These products can be considered as forerunners of future production.

In Fig. 7 the writer has drawn up an axonometric view of a kitchen (such as planned by the Association for P. and R.R.) indicating a few of the applications to which plastics have been put.

Curtain Rails

Extruded plastics have been manufactured in sections similar to metal curtain rails. The advantage of the phenolic bar over the metal is that the phenolic material will not be attacked by steam and does not require surface treatment or polishing. These thermo-hardening rails cannot be bent at the overlaps as it is customary with metal bars, and some special sections have been produced to overcome this difficulty by designing the section of the laths composed of two rails instead of one. This double rail and the pelmet is formed into one single lath, which can be cut practically to any lengths to suit the size of the window.

A thermoplastic curtain rail has also been known on the market. This type of rail is pliable and can be used much the same way as the metal type. For kitchens and bathrooms, where the double action of heat and steam is practically inevitable, the writer prefers the phenolic rail, for its better dimensional stability.

Resin-bonded Plywood Panels

There is probably nothing better for the panelling work than resin-bonded laminated woods, either in the form of plywoods, or (for thicker panels) block-boards and laminboards, as the resin treatment rules out those few objections which can be made against ordinary ply-woods. (Some more detailed notes on wood-resin combinations appeared in earlier issues of this journal.)[17]

Knobs and Fitments

Phenolic and urea-type mouldings have been so popular for the past few years that it seems strange to see that some other materials are also being used occasionally. Simple extruded sections, cut to the required lengths, are used as well as cast phenolics and compression-moulded fit-ments.

Cups, Beakers, etc.

The use of urea cups, plates and similar items has become quite popular and there is a small set on many plate-racks for use in the nursery.

Draining Boards

Compression - moulded urea-formaldehyde draining boards have been produced in the past. It is claimed that the use of such draining boards is more hygienic than that of the usual types. Although the technical reasons for this do not seem quite obvious, it is a very interesting application and shows the versatility of the colourful urea resin.

Tap Parts

Taps of the press type, with black phenol-formaldehyde buttons, are fairly well known. More colourful applications have also been produced by using cast phenolics for the crutches and covers of bib-taps of the "screw-down" type. The fact that the resin is untarnishable and colourful and does not require polishing is probably the main reason for this kind of application.

Refrigerator Parts

Inside the refrigerator we find urea-resin freezing trays, in the walls there are sometimes plastic insulating materials. Doors have been produced both of laminated plastic or moulded polystyrene.

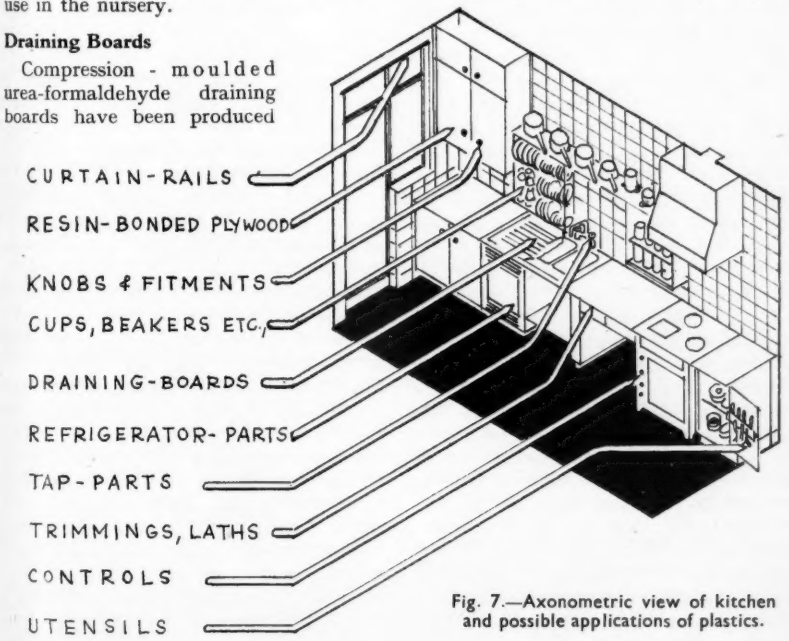


Fig. 7.—Axonometric view of kitchen and possible applications of plastics.

An application of injection-moulded polystyrene parts for the outside panels (frames) is also known.

Trimmings

The use of trimmings made of cellulose-acetate-butyrate is both practical and pleasing. The writer described the aspects of such components in more detail[2] on these pages earlier.

Controls both on electric and gas stoves are often made of phenolic resins, and we need not enumerate the applications in electrical equipment, as these have actually ousted most "traditional" materials.

Utensils

Although utensils such as meat-mincing machines, sieves, jelly-moulds, and smaller tools, such as knife sharpeners, cannot be regarded as architectural elements, the size and shape of such components is important from the point of view of their storage problem, which, again, brings us to the size and shape of the utensil cupboard. (Such a utensil cupboard has been drawn up by the Association for P. and R.R.). It might be of interest therefore to mention that the plastics industry has produced numerous items for making such utensils better and cheaper. Labour-saving devices, such as small electric beaters, have been produced with plastic housings, and many an item such as egg-slicers and lemon-squeezers have been made out of thermosetting materials. It can be anticipated that there will be even more such devices available and it is doubtful whether the utensil-cupboard as it has been planned (see Fig. 3) is capable of holding all in a satisfactory manner. It has to be borne in mind that it is not satisfactory to store plastic utensils in a crowded space, together with such robust and heavy articles as, say, cast-iron mincers.

It has to be noted that the above comments on plastics as part of kitchen equipment is only meant to give an outline of the diversity of the parts which plastics have already played, and it is by no means a complete survey. The compilation of all interesting uses of plastics would take up an enormous space. The use of paper-based phenolic veneers as surfacing materials, for instance, is one of the well-known applications of plastics. Designers and architects may also give some consideration to the possibility of using plastics in conjunction with terrazzo flooring. An experimental application of cellulose-acetate-butyrate laths has been described in these pages.[5]

Future Possibilities

It becomes increasingly obvious that the co-ordination of the various "standard sizes" is only possible if there is a standard plan for the assembly and arrangement of all items which form part of the kitchen. The aim should be to cut down the site-work to a minimum, without sacrificing the flexibility of design, and this can only be achieved by a system of well-planned workshop assembly. The writer has designed a system of workshop assembly (or, if you like, prefabrication) of kitchens (see Fig. 8). This plan is largely based on the recommendations made in the Report[1] already mentioned. This system would involve modifications compared with the plan seen on Fig. 4, to make workshop assembly and mass production possible. These modifications are the following:—

(a) The writer does not suggest standardization of the size of the kitchens or the position of the doors and windows, as these are decisions to be taken by the architects and clients, and whether there are hatchways to dining-rooms or dining recess in the kitchen itself are personal considerations which cannot be predetermined or dictated by manufacturers.

(b) The two units designed contain everything which is the minimum requirement of every up-to-date small kitchen of the town dweller. These units are of transportable size, built into a skeleton work. That means that instead of fixing cabinets to walls and ceilings in situ each unit is entirely self-supporting and can be used as the skeleton for light walls.

(c) The line of the skirting is con-

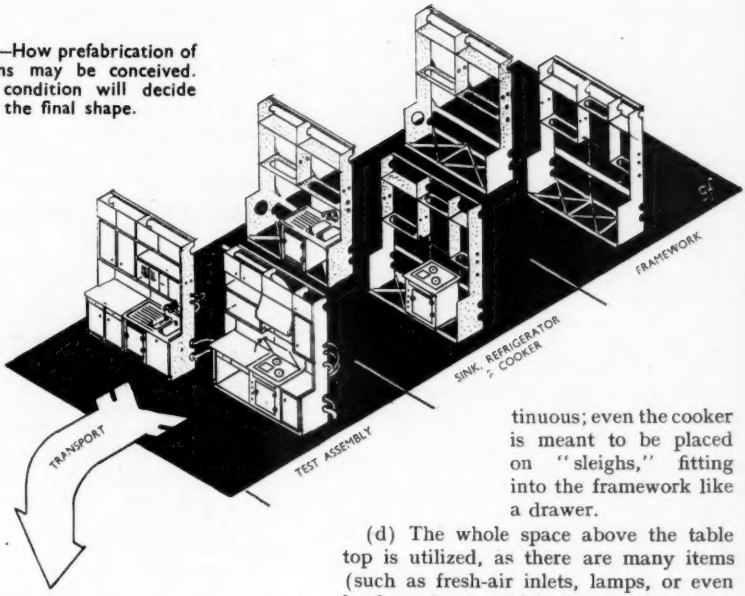
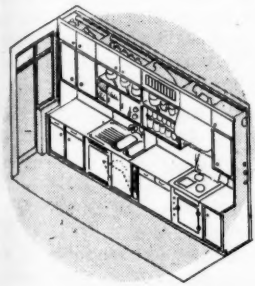
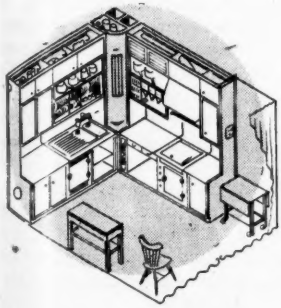


Fig. 8.—How prefabrication of kitchens may be conceived. Local condition will decide the final shape.





tinuous; even the cooker is meant to be placed on "sleighs," fitting into the framework like a drawer.

(d) The whole space above the table top is utilized, as there are many items (such as fresh-air inlets, lamps, or even loud-speakers) which it may be necessary to "build in." Even if such things are not required, the additional shelf space is certainly not superfluous. (In fact, shelf space is never enough.) This system of utilizing the space from the floor level to the ceiling on an elevation surface of approximately 100 sq ft. is also necessary to avoid site work to match up tiling (or other wall protection) with the furniture units, otherwise necessary (compare Fig. 7).

Such a plan, of course, involves all problems which invariably emerge in every scheme of prefabrication, which cannot be treated here in full, as the main object of the present investigation is to tabulate those possibilities which have some significance from the point of view of the development of plastics. It may be of interest, however, to outline the manner in which the plan intends to be applicable to individual requirements.

Mass Production versus Individual Design

In the case of the construction of kitchens, local and individual require-

ments are so varied that the manufacturer should not go farther than assembling units such as are seen in Fig. 8. It is the architect's job to decide upon everything else, although some guidance on the position of doors, windows, flooring problems could be supplied by the manufacturer. The storage space available in the units may be sufficient for small flats but certainly not enough for a larger family. The kitchen may require more shelves, as well as an additional work-table.

The units themselves would contain cooker, sink and refrigerator and a number of cabinets in every case. But allowance has to be made for personal and individual requirements as to the fitments desired in the upper parts of the framework. In some cases there may be an air-conditioning plant to be taken into account and fresh-air inlets to be allocated. Some people prefer to store groceries on open shelves, others, again, like to keep everything well protected from steam and require shelves with sliding glass doors. Such questions are important because we can attain only a certain point in prefabrication, and to find this limit is absolutely vital for the manufacturer in estimating quantities.

The question of materials is both a technical and an individual matter. It would be rather dangerous to put undue preference on one material, although it is possible to make all cabinets in wood, or to produce an all-aluminium, an all-steel, or even an all-plastic kitchen. It is presupposed, of course, that the assembly workers are capable of handling different materials, and that the cabinets and refrigerators and all other smaller units are being manufactured in alternative materials and finishes, but all to the same standard fixing sizes, so that they can be interchangeable.

Luxury or economy may find their expressions in the choice of the elements, but this does not necessarily affect the sizes. It must be stressed that the two units are only meant for housing the elements which are absolutely necessary for the provision of meals. Whether there is a broom cupboard necessary in the kitchen, or whether it is placed elsewhere, or whether hatchways, cabinets for electric and gas meters are also placed in the kitchen is a matter of circumstances. Certainly the plan can be used in a flexible manner to suit such requirements.

Suggestions for the Future Applications of Plastics

Provided that the above-mentioned manner of prefabrication is carried into effect, there are a number of applications for which plastics can produce alternatives of high practical value. As the work of planning and standardization is being developed at the present moment by the authorities, and as the various firms specializing in prefabricated structures are already well ahead with their schemes, it appears to be timely to put forward a few possibilities.

The suggestions below are based on nothing more solid than the writer's personal opinion, and he may prove to be wrong in some of his conclusions, but these suggestions will at least create a sufficient basis for constructive criticism.

The Framework.—The frames or skeletons seen in Fig. 8 can be made of wood and metals in a number of variations.

(a) Solid wood alone,
(b) solid wood and blockboards combined,
(c) rolled-steel sections (laths),
(d) rolled-steel laths and pressed-steel sheets combined.

The frames must be strong enough to withstand transport, even when laden with the cabinets and other units, without distortion. Certain parts of the skeleton must have good nail- and screw-holding capacity. Dimensional stability in the presence of moist air and steam is imperative, as well as imperviousness to corrosion. As both wood and steel have certain inherent disadvantages (which can, of course, be overcome), we could not say that any of the four mentioned possibilities is ideal.

On the other hand, it is obvious that none of the unreinforced plastics can be

considered for such purposes. It is, however, the combination of wood laminæ with thermosetting resins which will give, eventually, a range of rails and boards suitable for the construction of this type of frames. Many of the wood resin combinations which are often referred to as "densified wood,"[6] "improved wood," etc., have proved to be excellent although costly structural materials. After the war the structural engineer will have a range of such materials at his disposal in various densities, with various tensile strengths so that the gap between the strength of steel and that of solid wood will almost be closed. Besides the plan-parallel boards, we shall probably have a number of jointless circular as well as eccentric frame sections, produced by continuous winding processes,[7] and also possibly rectangular sections with curved edges. Such structural elements will prove ideal to be used for workshop-assembled frameworks. Wherever nail-holding surfaces are required the combination of laminæ can be varied as to present a solid wood surface on such portions. The companies engaged in the production of such resin-wood components will certainly take the architectural requirements into consideration when the time comes to think of peace-time standards. It is to be hoped that prices will approximate those of "standard" materials.

Finishes and Adhesives.—The importance of enamels of the thermosetting variety can hardly be over-estimated. The fact that hard and heat-resisting finish can be oven-baked on organic materials opens up a tremendous vista for architectural design. The treatment, of course, is, and probably remains, a workshop operation as the temperatures required for the formation of such enamels range from 195 degrees F. to approximately 280-290 degrees F., according to the formulation of the resin, or curing time prescribed. There is also a possibility of using certain accelerators to reduce curing temperatures, but it is very likely that the real field of usefulness of these resins will be in prefabricated workshop-assembled structures.

There are mainly three types of finishes which come into consideration for specific work, such as the treatment of kitchen equipment, namely, the phenolic, urea and melamine types. These three main types, of course, can be formulated in endless varieties, according to the requirement of the prefabricator. The gap which existed so far between enamels of the vitreous type and the air-drying cellulosic finishes and oil paints will be filled by the use of these thermosetting resin finishes. Already there have been some products, such as boards treated with urea-resin, which have met with a certain amount of success. The fact that architects who know a lot about good paints have little information on thermosetting plastic varnishes is probably due to the custom that painting is a job which is normally carried out on the site. By shifting the process of finishing from the site to the workshop, as prefabrication gains ground, we shall probably see more of these organic enamels. Admittedly, some resin finishes are not only harder than usual coatings but, unfortunately, also more brittle. This is, of course, a matter for application research, as there are several means and ways to overcome such difficulties. There is, of course, little information on the subject of comparative impact strength, as the whole field of applications is relatively new. The newest (and probably the most promising from an architectural point of view) is Beetle-Melamine resin, but, of course, we cannot expect to have much information of a material which was "born" in 1940[8].

Adhesives and putty-like compounds containing a certain proportion of thermoplastics are widely used, but it is more than likely that thermo-hardening products both of the accelerated and the oven-curing varieties will become customary in the pure-fabricator's workshop. As the writer has described adhesives in more detail[7] previously, let us consider one example only for the use of thermosetting adhesives. Every cabinet which needs internal fitments or drawers has to

be fitted with rails or other supporting elements. These are generally screwed to the bodywork. With the use of thermosetting resin adhesives, hardwood laths could be simply stuck to one of the surfaces of the plywood and would be almost as firm as two metal pieces welded together. This may fill some cabinet makers with horror, but such a joint is technically possible.

Vertical Panels and Table Tops

The vertical surface above the working table, sink, etc., must be waterproof, damp- and heat-resisting (Fig. 8). There are similar conditions for table tops, shelves and all panels necessary in the construction of the kitchen units. These panels must be also reasonably shock-proof and impact-resistant.

Steel (with vitreous enamel) and light metals would probably give satisfactory solutions, as the extensive use of fire-clay cannot be regarded as ideal for such transportable structures. As steel is probably too heavy if made in a suitable gauge, light metals, wood and wood fibre compositions will probably be considered more favourably, and probably asbestos cement as well. Plastics have to play a supplementary role with all these materials, as surface protective or binding agents, or impregnators. The finishing and surface treatments of light metals and asbestos cement with urea resin have been well tried out, but panels of the organic type need further research.

The design of table tops is of great importance, and, whatever the material, it should be shaped as a jointless sheet bent down on the front and bent up on the back where it joins the vertical panel. Table tops of a similar shape can be seen in our illustration (Fig. 6).

The technical possibilities of producing such shaped " plastic " panels are:—

(1) Resin-impregnated wood of the laminated type.

(2) Resin-bonded plywood.

(3) Low-density wood fibre-board, moulded to shape and then impregnated and autoclaved.

(4) Laminated phenol-formaldehyde (modified with rubber compounds) and moulded to the required shape.

(5) Fabric - filled, compression-moulded thermosetting resin, of the shock-resisting grade.[9]

Besides these variations (all of which have certain merits, but also disadvantages), methods are being developed for combining wood, resin, and woodpulp by processes suited to wood-workshops.

Insulating Material for Cooker and Refrigerator

The arrangement of the cooker, side by side with furniture units presents a problem of insulation. The insulation of the refrigerators and the cookers generally calls for two different types of material, because there is no " all-round " insulating material for both high and low temperatures. Glass silk, however, combined with certain resins, may result in such an all-round insulation, a fact which may be of some interest to plastics manufacturers.

The only drawback of glass-silk insulation is the difficulty of handling and fixing. Relatively, newer types such as the " Verisolant " (Swiss) or " Vetroflex " (not to be confused with " Vitroflex ") have been produced by spreading out the glass silk into several layers and each layer has been prepared with a gelatine preparation, thus locking the surface fibres. These layers are subsequently stitched between two roofing felt or paper covers. With the use of thermo-hardening plastics, glass silk could be worked into light insulating slabs of such standard sizes as are required both for domestic refrigerators and cookers. This idea requires, of course, close consideration from a thermodynamic point of view. It is very likely that such insulating materials would retain the excellent qualities of the glass silk itself, provided that the fibres do not get entirely locked in the inside of the slab. The weight of glass silk itself is approximately the same as that of cork. For a comparison, the table (p. 407) gives some of the characteristics of a few insulating materials generally used for refrigeration.

	Weight, lb./cu. ft.	Thermal conductivity "K"	Mean test temp., °Fahr.	Authority
Cork	9—14.5	0.29—0.32	90	C. W. Glover
Glass silk	10.00	0.21	40	C. W. Glover
Wood pulp	16.9—19.5	0.343	90	U.S. Bureau of Standards
"Isoflex"	0.75	0.32	—	Manufacturer's publication

It can be seen from this table that glass silk compares quite favourably with low-temperature insulators. The use of cork for high-temperature insulation is limited by the impregnating material used. Wood-pulp board should not be exposed to heat over, say, 280 degrees F., and "Isoflex" (cellulose acetate) should not be used in the presence of temperatures over 167 degrees F.

The heat conductivity (k) of glass silk of the "Vetroflex" type is claimed to be not more than 0.337 B.T.U. per hour, sq. ft., degrees F., 1 in., in the region of 390 degrees F., which is not an undue increase compared with the figure given as 0.233 at freezing-point temperature.[10]

All-plastic Components

There are a number of items in the suggested prefabricated kitchen units which can be designed entirely in plastic materials by processes such as extrusion and compression moulding. It would take up considerable space to describe these with detail plans.

Skirting Rails

An extruded phenolic skirting could be produced in a similar manner to the sketch shown in Fig. 4 of the article which appeared in the April issue of this periodical.

Drawers for the Vegetable Cupboard

Plastic moulded trays and drawers have been described[7] earlier, and such drawers could be produced with perforations as to allow sufficient air circulation.

Plate Rack

As the sizes and quantities of plates and cups of an average household do not vary to a large extent, it is fairly easy to design a plate rack with a holding capacity to suit a large number of homes. The place allocated for the plate rack can be seen in Fig. 8 in our example, and the writer suggests that the design should be a simple one, in the shape resembling a slotted sheet. Two such identical sheets could be fixed into the cabinet or between the shelves.

Both compression-moulded phenolic and urea resin are suitable in shock-resisting grades.

Such a plate rack can be designed practically without corners and edges, thus making it easy to keep clean.

Grocery Containers

The inside of the grocery cupboard and the compartment for dry groceries (which is over the work table) offer various applications for plastics. Certainly there are better solutions for storing dry groceries than to keep an unimaginative row of tins.

Some groceries should be kept in silo-type containers, with transparent slot windows, a screw top and bottom outlet.

It is not necessary to describe such fitments in much detail, as it is quite certain that, when the time comes, the plastics industry will be ready to produce the imaginative, colourful and useful articles that will be required.

(To be continued.)

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(1) *"Broadsheet" No. 3: Association for Planning and Regional Reconstr.* **(2)** *"Plastic Building Components," "Plastics," April,* 1942. **(3)** *British Standard Inst., B.S.S.* 645, 1935. **(4)** *"The Hub of the House," "Architects' Journal,"* 27 *Aug.,* 1942. **(5)** *"Extruded Plastics," "Plastics," Feb.,* 1942. **(6)** *Dr. V. E. Yersley. "Laminated Materials," "Trade and Engineering," Sept.,* 1942. **(7)** *"Plastic Building Components," "Plastics," Aug.,* 1942. **(8)** *"Plastics in* 1940," *"Fortune," Dec.,* 1940. **(9)** *British Standard Inst., B.S.S.* 771, 1938. **(10)** *Balzaretti Modigliani: "Dati Tecnici del Vetroflex."*

World's Industry Employs Plastics
(continued from p. 395).

greater percentage of resin than the interior mass in close proximity to the shaft to which the sleeve is affixed. During curing, plastic-impregnated bearings of this type (produced by winding a textile strip soaked in a plastic composition around the shaft) are maintained in constant rotation, pressure and diameter being held at the desired level.

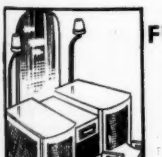
TEXTILES

Weathering tests on cellulose acetate and cellulose nitrate films are considered in a report by Y. Inone ("Journal of the Cellulose Institute," Tokyo, Japan, 1941/17/31). The author deals specifically with the influence of plasticizers and pigments on the weathering resistance of films on fabrics. Films were about 0.1 mm. thick, and tests were carried out by placing specimens of the films on racks inclined at 45 degrees and facing south. Rocks were mounted on the laboratory roof. Concerning acetate films, 20-35 per cent. triphenyl phosphate, triacetin, or dibutyl phthalate are the most satisfactory plasticizers where high resistance to weathering is required. Benzyl alcohol gives films which become brittle in a few months. Excess solvent or plasticizer should be avoided for acetate films. Tricresyl phosphate gives opaque films of low durability. Clear nitrate films tend to break down rapidly (one month in summer), durability being improved by adding large quantities of mixed plasticizer; additions of eugenol or vanillin act as useful stabilizers. For both acetate and nitrate films, additions of pigments of low light permeability increase durability. Such pigments are carbon black, red oxide, zinc oxide, aluminium powder. The effect of such additions is to prevent the absorption of ultraviolet rays which are highly destructive. Where acetate film is applied to fabric it is deemed essential to add pigment in order to prevent degradation of such fabric by light. The author notes that weathered acetate films tend readily to loosen in wet weather. In general, water absorption tends to increase in weathered nitrate and acetate films. The author points out in the report the mechanical effects of water absorption upon the fabric base of doped structures. The fabric tends, initially, at least, to lose its tautness and to sag, this causing anomalous extension of acetate films in particular.

CHEMICAL

Welding thermo-softening plastics has become so widely practised that recently the V.D.I. has issued general recommendations on the technique (V.D.I. Zeitschrift, 1942/86/523; V.D.I. report 2006, Jan., 1942). For each plastic material it is essential that specific conditions be observed, and it is to be noted that the following recommendations are to be followed only for straight polyvinyl chloride without fillers and without excessive quantities of plasticizer. Flow point of polyvinyl chloride is about 200 degrees C., and this represents also optimum welding temperature, which must be carefully controlled and maintained. Heating is by means of hot air blast, or gas stream. Various compressed gases, such as nitrogen, carbon dioxide, hydrogen and oxygen, may also be used for heating, but selection of gas must be based on economical considerations and those of safety; fire, explosion or gassing of operatives are hazards to be avoided. Gas stream is electrically heated, or, alternatively, may be brought to required temperature by hydrogen flame, coal gas, acetylene, propane, etc. Where welding is conducted without a

filler rod, components to be joined are warmed to flowing temperature and then brought into contact under pressure. In this case, heating may be effected by means of electric hotplate, or the surfaces being joined are pressed together and are then caused to " rub," so that the necessary heat may be generated locally. One part, for example, may be rotated in a lathe the other being brought up against it. (It is interesting to observe that polystyrene is particularly amenable to welding by this means.) When welding with a filler rod, seams, corner joints and butt joints may be of the same form as employed for metal welding, with Vees of 60-75 degrees with a gap at the apex of 0.02-0.04 in. to facilitate the running in of filler rod. Wherever possible, welding from both sides is recommended, i.e., double Vee. Filler rods may be of the same composition as the materials being welded, or may have small additions of plasticizers. Rod diameters of 0.06, 0.09, 0.12 and 0.16 in. are suitable, and must be selected according to design, joint shape and general accessibility of the work. Welding technique resembles that for metals; rod and heating device are held as in the case of right-hand welding. The filler rod, it should be observed, must be brought into contact with the base and caused to flow and adhere; unlike metal, the fluid state is not assumed. Although welding in a horizontal position is easiest, vertical or overhead welding may also be done.



FURNITURE

Protective and decorative coatings are dealt with by J. J. Matiello, technical director of Hilo Varnish Co., in a recently published book. Very full treatment is given to the natural lacs, gums, and the synthetic resins. **Low-grade lumber** may, according to a note in " Scientific America," September, 1942, be improved by the use of a new synthetic-resin-bonded knotting. Furthermore, high-grade lumber may be doctored with this composition where necessary. A special feature of the medium lies in its non-shrinking qualities; even when used to fill 2-in. dia. knot holes it gives perfectly satisfactory adhesion without gaping or suffering surface distortion.

MISCELLANEOUS

Improvements in pre-moulding technique are described in D.R.P. 717914 (H. Roemler A.G. and Anton Fuchs). Moulding powder is tableted and heated and transferred directly to the moulding press. **Shaped bodies containing thermosetting plastics** are produced by an injection moulding system. According to D.R.P. 718281 (Richard Hessen and A. Nowack A.G.), matters are so arranged that, on injection of the mass from the heated injection space through a heated sprue into the moulding chamber, final heating to curing temperature is effected in the first injecting chamber, so that the resin enters the mould at curing temperature, thereby hastening curing and so increasing output of the machine. **Impregnation of bibulous sheet,** say, paper, with synthetic resins is described by F.P. 869396. The patent covers the use of a succession of baths, the technique being designed to ensure uniform impregnation. **Sheet and plate produced from polyamide resins** are described in F.P. 869,242. The polyamides are swelled in a suitable organic medium diluted with water, at about 30 degrees C.; surplus swelling agent is then removed and the swollen mass heated. It is found that its softening point under these conditions is much lower than in the dry, unswollen state, and that, furthermore, material so swollen and heated is highly amenable to moulding.

PRODUCTION NEWS

Raw Materials, New Plant, Works Organization, Control Apparatus, Research, Personal and Trade Notes

STEAM JET OPERATION.—The use of steam jets for forced draught in steam boilers, refuse destructors and other furnace settings is well known, but there are many other interesting and specialized applications in the chemical and allied industries. In a number of cases the use of steam jets for such purposes as conveying liquids through pipes, agitating, oxidation by aeration, and localized application of exhausting or blowing is superior from the net points of view to any other method. Also for the best results for purposes such as boiling water or other liquids in tanks, vats, pans and other apparatus by direct admission of steam, it is essential for economical results to use a scientific design of jet, which also applies for gas producers.

In this field much interest attaches to the work of Meldrums, Ltd., of Timperley, near Manchester, which, nearly half a century ago, was one of the chief pioneers in the use of steam jets for forced draught, first used for its destructors, and has since specialized on many other applications of steam jets.

Typical, for example, are acid elevators made either of cast iron, gunmetal, regulus metal, ebonite, or the firm's own special acid-resisting metal, consisting of a relatively small fitting connected to a source of steam supply and having inside a special design of jet, together with suction pipe and discharge pipe for the acid, or any other liquid of an acid or corrosive character. The equipment is available in a number of standard sizes with a capacity from 200 to 5,000 gallons per hour.

By this means acid or other liquids, in simple and efficient fashion, are lifted, say, from a tank by a suction or elevator pipe and discharged to an overhead tank or required receptacle. In fitting, the only precaution is that a short length of lead steam pipe should be included to the ordinary iron steam supply pipe, with a control valve to eliminate any possible corrosion.

With regard to agitation for the dissolving of chemicals as well as aeration the jet agitator is often the most suitable, being cheap, small in size, and very easily applied, with no moving parts to get out of order, the only accessory being a steam valve. These steam jet agitators are made in 12 standard sizes, with a steam pipe from ½-in. to 4-in. diameter, while the inlet pipe for the air, which is injected by the action of the steam pipe and blows through the liquid, is from 1-in. to 8-in. diameter, corresponding to the delivery of 1,000 to 61,000 cubic ft. of air per hour.

LIABILITIES ACT OF 1941.—One of the main objects of the Act is to provide means by which small businesses, submerged by war conditions, may be saved from destruction. A trader who is in financial difficulties can, subject to conditions, get relief from his liabilities without incurring the stigma of bankruptcy, if he can show that because of war-time circumstances he has become unable to meet his outstanding obligations or could meet them only by a realization of assets which would involve the sacrifice of his business, or prevent him from starting again after the war, or deprive him for the time being of his means of livelihood.

Traders who would like more information about the Act and its working should apply to the local Liabilities Adjustment Officer. The Registrar of the County Court will always be ready to put them in touch with the nearest office. The Board of Trade, too, will be glad to help in any way they can. Inquiries should be sent to Industries and Manufactures Dept., 1, Millbank, S.W.1.

BRITISH STANDARDS INSTITUTION.—At the Annual General Meeting of the British Standards Institution, Sir Percy Ashley, K.B.E., C.B., accepted the Invitation to remain as Chairman of the General Council. Dr. E. F. Armstrong, F.R.S., formerly Chairman of the Chemical Divisional Council, was co-opted as a permanent member of the General Council. The Chairman reported the recognition by H.M. Government of the Institution as the body for the issue of national standards, with the exception of those issued by the Medical Research Council in the British Pharmacopœia and Codex.

Since the last meeting the Institution has published 160 new and revised standards, bringing the total issued to 1,300. These include war emergency specifications prepared at the request of the Ministry of Aircraft Production, Board of Trade, Ministry of Home Security.

Resinoids and Other Plastics as Film Formers

By B. J. BRAJNIKOFF,
Consulting Electrical Engineer

XIII.—Electrochemical Aspects of High-Polymeric Systems

ALTHOUGH the vigorous development of physical chemistry commenced only 50 odd years ago, its foundation may be traced back to 1751-1753, when it had been initiated by the great Russian savant, Professor M. B. Lomonosoff,[165] in his lectures on physical chemistry, including his original kinetic theory of gases.

This union between physics and chemistry has led, indeed, to the remarkable growth of the industrial chemistry at the end of the past century.

Particularly fruitful has been collaboration of chemistry and physics during the past three decades, since Rutherford's famous experiments on the structure of the atom at the Cavendish Laboratory in Cambridge and the inauguration of chemical physics.

Electrical Factors Involved

As has been established by recent researches of Houwink,[166] the physical behaviour of resinous materials, especially the deformation properties of the films obtained from them, can be correlated with the structural aspects of the molecular development.

Thus, the valuation of the complex mechanical properties, comprising hardness, elasticity, disruptive strength, resistance to impact, electrical characteristics, adhesive power, etc., which are all interdependent, is inseparable from the fundamental study of matter from the electrochemical standpoint.

It should not be forgotten that electrical phenomena at interfaces also play a part in the cohesional work, which is influenced by such variables as hysteresis, heterogeneity of the solid surfaces, boundary potentials and double layers, and the like.

It has recently been shown by a number of investigators[167] that monomolecular layers can be obtained in the same states of aggregation as three-dimensional substances. Some of the workers have succeeded in devising methods for studying the mechanical properties of the monolayers produced by the two-dimensional polymerization and condensation, as well as carrying out various chemical reactions with monomolecular films, such as esterification, oxidation, and so on.

A number of methods has been devised for studying the mechanical properties by measurements of the shearing strain and the performance of films in the liquid and the solid states. The critical examination of experimental results to date proves the existence of various reactions of polymerization and polycondensation in the monolayers with typical differences in their mechanical characteristics. These types of two-dimensional polymers reflect the various possibilities of the course of the two-dimensional reactions depending on the presence in the reacting molecules of bi- or polyfunctional groups.

Electrical processes also play an important rôle in all the phenomena of diffusion of fluids in and through membrane-forming organic solids.[168] This interpretation appreciably helped in understanding the chemical and physical structures of the diverse polymers, such as resins, cellulose, rubbers and the like, either per se, or as composite products, where they act as modifying agents in the form of coatings, impregnants, etc.

On the basis of such investigations it is possible to deduce the laws of diffusion kinetics for various types of flow of gases (especially hydrogen and helium),

vapours (carbon dioxide, ammonia, etc.), water and organic liquids, through different membranes.

Certain regularities connected with the mechanism of gas transfusion, such as molecular flow, activated diffusion, streamline flow, etc., thus afford a useful method for classifying the numerous groups of membrane-forming plastics by arranging their susceptibilities to a given fluid (e.g., air) in a permeability spectrum, by means of the logarithm of permeability of specified films (which may be designated as the " breathing coefficient " of plastics).

Electrical Structure of Matter

It is important, therefore, to inquire into the existent state of knowledge of the atomic physics in so far as it has a direct bearing upon the subject under discussion.

Whereas the old atomic theory held that the atom is the limit of the divisibility of matter, the modern electronic theory postulates that the atoms of a substance consist, in their turn, of the separate elementary particles or corpuscles of two kinds—protons and electrons, the former being the carriers of the elementary positive charges and the latter of the negative charges.

In a quantitative sense the charges of the proton and electron are equal to one another; however, the mass of the proton is a great many times larger than that of the electron. The number of protons and electrons in a single atom, and their mutual arrangement are identical for all atoms for a given substance and determine its chemical properties. In the event of one or several electrons being split off from the atom of a given body, the atom is converted thereby into the positive ion. When an atom acquires an extra electron, it is then negatively ionized, being transformed into the negative ion.

The simplest in its structure is the atom of hydrogen, consisting of one proton and one electron. The electron is the limit of the divisibility of the negative electric charge, i.e., it represents that minimum of the negative charge which is capable of independent existence. The positive ion of the hydrogen, left after the removal of electron, containing the main mass of hydrogen atom, is the proton.

On the basis of a series of investigations, among which Millikan's researches deserve special mention, it may be taken that the charge of electron is $e = 1.592 \times 10^{-19}$ coulomb. The mass of the electron is only 1/1,840 of that of the hydrogen atom (the mass of the proton); that is, equal to

$$\frac{1.663 \times 10^{-27}}{1{,}840} \text{ gr.} = 0.904 \times 10^{-27} \text{ gr.}$$

The extremely small dimensions of the atoms preclude the possibility of studying their structure by means of the direct observation. It is only by resorting to the specially devised methods of indirect exploration and inferences, as, for example, Rutherford's experiments demonstrating the reflection of α-rays (the repulsion of the positively charged helium atoms) from the positively charged particles in the atoms of matter under the investigation, phenomena in the magnetic field, as well as the examination by X-rays, that it has been possible to arrive at the present understanding of the structure of the atom.

In the hydrogen atom the spinning electron moves in a definite closed trajectory—a circular or elliptical orbit, whose centre is the positively charged atomic nucleus (with the normal radius of the orbit of the order of 0.53×10^{-8}cm.), the nucleus itself occupying a very small part of the atomic volume.

The motion is performed under the influence of the force of attraction, which is exerted by the positive nucleus on the electron in a manner analogous to planets in the Solar system, which describe their orbital motions due to attractive force of the sun. Here we have, as it were, a planetary system in a sub-microscopic scale. In this interpretation the molecule of hydrogen can be depicted as consisting of the two nuclei situated along the axis perpendicular to the electronic orbital plane.

The experiments with various chemical elements showed that the deviation of α-rays is effected by the nucleus of the atom and contains so many positive charges as many units there are in the atomic number of a given substance. The analysis of Röntgen spectra of different bodies also indicates that the number of active positive charges in the nucleus and the number of its outer electrons are equal to the number allocated to chemical element in the periodic system.

Thus the outer electrons describe orbits whose loci are within the spheres of different diameters, while the number of electrons in the outer sphere may vary without altering the chemical nature of the atom; that is, the chemical element remaining the same as before, the only difference being that the increase in the number of electrons, as compared to the neutral electrical state, corresponds to its negative ionization, and the decrease of electrons effects the positive ionization.

The nucleus has been found to possess a complex constitution, the exploration of whose actual nature has hardly begun.

The study of the radioactive emanations of great penetration in recent times has revealed the existence, besides the protons and electrons, also of other elementary components, taking part as structural units in the atomic architecture: the so-called neutrons and positrons.

The neutron represents a neutral particle, possessing no charge and having a mass equal to the mass of the proton, the positron being a positively charged constituent, with the mass equivalent to that of the electron. The neutrons and positrons may be regarded either as particles capable of independent existence, or elementary components, which by their union form the proton.

The Definition of the Unit of Electric Charge

The absolute value of the elementary electric charge can be directly calculated on the basis of Faraday's laws of electrolysis. The fundamental unit quantity of electricity, the coulomb (or 1 ampere/second), is that quantity, which deposits 0.001118 gramme of silver, when passed through an aqueous solution of silver nitrate. The electrochemical equivalent of a substance is defined as that mass which is liberated by the passage of 1 coulomb. Since the weights of different substances released in equal time by the current of the same strength are proportional to their equivalents [i.e., in the ratio of the quotients of the atomic or molecular weight divided by the valency of the respective element], it follows that the amount of electricity transported by 1 gramme-equivalent of a body represents a very important constant. The atomic weight of silver and hence its equivalent weight (as univalent substance) is 107.88, which by division gives $107.88/0.001118 = 96{,}494$ coulombs of electricity (one faraday).

The Electric Charge of the Electron

A hydrogen ion has one elementary positive electric charge; to liberate one gramme-atom (or gramme-molecule) of hydrogen requires the expenditure of one faraday, that is, 96,494 coulombs. The gramme-atom (or gramme-molecule) of any substance contains 6.06×10^{23} atoms (or molecules), according to the Avogadro or Losschmidt number; whence the quantity of electricity associated with each atom of a univalent element is $e = 96{,}494/(6.06 \times 10^{23}) = 1.59 \times 10^{-19}$ coulombs/atom, or $= 1.59 \times 10^{-20}$ absolute electromagnetic (C.G.S.) units, or $= 4.77 \times 10^{-10}$ absolute electrostatic (C.G.S.) units.

Since the hydrogen cation is an atom of hydrogen deprived of its one outer electron, then this value is, therefore, the negative electric charge of the electron. Divalent, trivalent, etc., atoms or radicals carry an integral multiple of this elementary charge corresponding to their valency.

The ratio of the elementary charge to the mass of the electron, or the specific charge is $e/m = (1.769 \pm 0.002) \times 10^{8}$ coulombs per gramme of a substance.

The Property of Atom-Valency

When in 1897 Professor J. J. Thomson finally established the nature of the cathode rays as the motion of electrons, and determined the value of the negative charge of the electron and its mass, he thereby laid the foundation stone of the atomic physics.

According to the laws of mechanics, the quantity of energy of the atom is the greater the farther from the nucleus is its stable (or stationary) orbit of the electron; a certain amount of energy (or "energy level," as it is termed), corresponding to each stationary electronic orbit, rapidly decreases as the orbits approach the nucleus. Of all the planetary electrons in the atom of each chemical element, a few, usually from one to eight, electrons are located at the farthest distance from the nucleus and are designated outer or valence electrons; they form the external electronic envelope of the atom. Since the weight of electron is negligibly small even in comparison with the hydrogen atom, it is clear that the atoms deprived of several electrons possess almost the same weight as the normal atoms.

An atom has a positive valency, if some of its outer electrons can be torn away from it; it is necessary, therefore, that these electrons should be situated at the envelope most remote from the nucleus. The numerical value of the positive valency equals the number of the valance electrons, by losing which the residues of the atoms pass into cations.

The negative valence of the atom of a chemical element is of different origin: this atom possesses the property of readily adding electrons so as to become a negative charged anion; experience shows that such an addition may be from one to four electrons; chemical elements with the negative valency greater than four are unknown.

The positive and the negative valency may be considered as the basic chemical property of an atom, with which are connected the other features of chemical elements, for example, the metallic (positive) or non-metallic (dielectric) character.

The periodic variation of the value of valency, which occurs parallel with the periodic change in the structure of electronic envelopes of the atom, leads, naturally, to the periodic law and the periodic system of the elements, which reflects the periodic alterations of these constants.

The positively charged part of the atom, its nucleus, carries the entire mass of the atom (with the exception of the negligible mass of the planetary electrons), from 1 to 92 positive elementary electric charges; as has been established by Rutherford, it is of the vanishingly small size, being of the order from 10^{-16} cm. in diameter for the hydrogen atom to 10^{-12} cm. in the atoms of the heaviest chemical elements.

The value of the positive electric charge of the atomic nucleus is the most important constant of the atom and of the chemical element. As had been found by Moseley in 1914 at the Oxford University laboratories, its magnitude, expressed in terms of electric elementary quanta, is equal to the atomic number of the chemical element; this striking discovery was subsequently corroborated by Rutherford and Chadwick, who, in 1920, determined the positive charge of the atomic nuclei for copper, silver and gold.

This quantity, further, directly determines the number of the planetary electrons in the atom, and since their distribution in orbits, chemical properties, the spectra of atoms, etc., depend on this number, it follows that, ultimately, all the properties of an atom are governed by the magnitude of the positive electric charge residing in its nucleus or, what is the same thing, by its atomic number, that is, for each atom the nuclear charge = the number of the planetary electrons = atomic number.

The chemical, optical and other properties of the atom are conditioned by the number of the planetary electrons, depending, in their turn, exclusively upon

the amount of the nuclear charge and not upon its mass. This finds its proof in the complete identity of the chemical as well as other properties of atoms of isotopes, whose nuclei possess different masses, but identical charge (pleiads). At the same time, in isobars, that is, isotopes of the equal atomic weight, which with the same mass display different chemical properties, the atomic nuclei have identical masses but different electrical charges and different properties. All this has been admirably demonstrated by the spectrographs of mass developed by Soddy and Aston since 1913.

As the chemical properties of the elements are expressed by the periodic system, it follows that the latter gives the systematic classification of matter according to value of the positive electric charge of their atomic nuclei, i.e., in terms of the atomic numbers as formulated by the modern periodic law.

Intermolecular Bonds

The union of atoms in molecules is realized by forces of electrical origin, whilst their intermolecular bond may be of the two kinds: (a) the polar bond, in which each of the two bonded atoms passes into an ion by losing its valence electrons, or taking up extra electrons, so that ions can also unite in the polar manner; (b) the non-polar bond, which is effected by means of electrons that are common to two or several atoms and formed by the valence electrons of uniting atoms which combine in the non-polar fashion.

The bond of purely polar nature, just as the non-polar bond, is of rare occurrence; in most cases the bond between atoms occupies a position intermediate between the polar and non-polar union. When it is nearer to the polar bond, i.e., if nuclei of both atoms attract the electrons with unequal force, then, obviously, there is the possibility of disintegration of the molecule into ions under suitable conditions, such as the presence of water, and combination of this nature does not differ in this respect from purely polar union.

The degree of ionization of the molecules in aqueous solutions can serve as an index of the character of intermolecular bond—the greater the ionization, the nearer the union approaches the polar nature. The basic cause evoking the formation of both ions and electrons common to the combining atoms, doubtless, resides in the tendency of each atom to build the most stable grouping of the electrons in its outer (valence) envelope—to equalize its number to that of electrons of the outer envelope of the helium atom, i.e., up to eight.

Amorphous and Crystalline Structure

When a substance in the gaseous phase passes into liquid and solid, it forms giant aggregations of atoms and molecules, in which the latter are bonded by the intermolecular forces.

The bodies thus formed may be either crystalline, characterized by a symmetrical arrangement of the constituent particles (anisotropic features), or of an amorphous character, the composition of which displays no regularity (isotropic property).

As a result of the discovery of X-ray interference by Laue in 1912, and further Röntgenoscopic studies by Bragg, it became possible to bring to light the nature of crystalline arrangements for a large number of substances. It has been found that they consist of a space lattice formed by three families of parallel planes (lattice planes) along three axes of co-ordinates, the intersection points (lattice points) being the loci of the elementary particles, usually atoms or ions, although a grouping of certain atoms may result also in a molecular lattice.

Special importance attaches to the case in which a large proportion of small crystals in the body are arranged in such a way as to point in the same direction, but have random angular positions about this direction as axis (fibrous structures). This constitution is typified by wood cellulose fibres, which are built up of submicroscopic particles (micelles) that are readily detected by their X-ray diffrac-

tion pattern. These structural units, each of which exhibits crystal-like behaviour, are oriented in a more or less regular fashion along the axis of the fibre. Every micelle, or crystallite, as it is usually called, possesses along this axis a definite periodicity, which is characterized by the recurrent length of about 10.3 Å.

Another example is provided by the polyvinylidene chloride, which, under the trade name of "Saran," has been recently marketed by the Dow Chemical Co., U.S.A. This plastic material is characterized by the property of being able to exist in the three different conditions: (1) amorphous, (ii) the normal crystalline unoriented form, and (iii) the oriented crystalline state, showing a lattice diffraction pattern.

Wave Mechanics

Omitting the details concerning the connection between the orbital motion of the planetary electrons and the emission of radiant energy by the atom, as postulated by the classical theory of Bohr, it may be pointed out that this investigator, in expounding his model of the atom, frequently drew attention to its many gaps and drawbacks, which became the more apparent as the volume of data in the respective branches of science grew larger.

The introduction of new experimental methods has made possible a much more profound study of phenomena, and resulted in fresh facts and theories, which, in a considerable measure, have modified the former notions on matter and the nature of the physical world.

Einstein's theory of relativity has ingeniously associated energy with the mass; the quantum theory rendered feasible the relation between energy and atomic structure. Thus, the energy becomes, as it were, equivalent to matter, light quantum (the photon) portraying something similar to the atom and, at the same time, remaining the wave propagated in space. The discovery by Davisson in 1928 of the phenomena similar to those observed in the propagation of typical wave processes (i.e., light), has led to further findings that in the motion of electrons their current (cathode rays) displays the phenomena of reflection from the surface of a nickel crystal and dispersion.

Since what is usually called matter has a complex constitution, comprising the electrons and protons, positrons and neutrons, it is evident that the motion of the material particles is analogous to wave motion. These considerations induced de Broglie to advance in 1925 the hypothesis that every mechanical phenomenon can be regarded as wave phenomenon, i.e., that it is possible to expect in it the propagation, interference and diffraction of waves.

This revolutionary concept, which recently was elaborated in detail by a number of the mathematical physicists, particularly by Schrödinger, Born and Dirack, has been developed into the science of wave mechanics, according to which the electron and the photon are regarded as possessing dual properties, being simultaneously both the corpuscles and waves, and are thus two aspects of one and the same phenomenon.

Molecular Co-ordination Theory

The high molecular compounds are distinguished from the molecular compounds of the "first order," or simple combinations of atoms, by the circumstance that they cannot be represented by means of the ordinary valencies of the chemical elements, and, for this reason, structural formulæ are inapplicable to them.

To ascertain the structure of the molecular combinations of the higher order it has become necessary to introduce a series of supplementary concepts and postulates, among which the most notable are those that form the principles of the "co-ordination theory," first propounded by Werner in 1891, and extended subsequently by Sidgwick on the basis of the latest data of chemical physics.

The properties of high molecular compounds show that, basically, they in no way differ from the ordinary combinations, i.e., the molecules of the first order; consequently, there can be no doubt that the

mutual union of atoms, both in the high associations and in the simple combinations, in essence, is indistinguishable.

With the view to explaining the mechanism of the formation of intermolecular associations, Werner assumes that atoms through their union to form the molecule of the ordinary type do not expend the total energy which they can emit for building the mutual bond; a part of this energy is left unutilized and may generate the mutual combination of molecules. Werner terms the usual valency of a chemical element, which is revealed in combining its atom with those of another chemical element—the primary, principal, or fundamental valency; and the unused residual valency, by means of which is effected the mutual union of molecules in the molecular complexes, he designates as the secondary valency.

According to Werner, in each molecular compound there is a central atom, to which are attached the groups or molecules by means of non-ionizable (non-polar) bond; i.e., in such a manner that water cannot effect either their ionization or separation from the central atom; these molecules and groups are regarded as contained " within the first sphere," nearest to the central atom, and their number is the " co-ordination number "; the central atom, together with these groups and molecules, constitute the so-called " co-ordination nucleus " or " co-ordination complex." Those atoms or residues of a molecular compound, which are split off in the form of ions in the aqueous solution, are reckoned to be situated in the " second sphere," more remote from the central atom, and are bonded with it through the principal (polar) valencies, which are ionizable by water.

Thus, the distinction between the primary and the secondary valencies is, in so far as the polar bond differs from the non-polar one, essentially, according to the ability to be ionized.

Whatever the interpretation, the existence of the central atom in molecular compound (which, in conjunction with its adjacent groups, forms a single whole co-ordination nucleus) is an established fact. This property is strictly selective —not every chemical element can give such a nucleus—and is limited by a definite number of uniting groups, the co-ordination number.

The quantitative treatment of the problem of interionic forces in the electrolytes has been furnished lately by several distinguished workers, chiefly by Hückel and Debye, and is generally in agreement with experimental observations over a considerable range.

Electronic Aspects of High Polymeric Systems

The old problem of the structure of organic compounds in presence of the double, triple, and conjugated bonds between the carbon atoms, the residual valencies, and various transformations of related combinations, under the influence of one and the same reagent, still remains new as ever.

Its comprehensive study by the Russian chemists, initiated in the past century by Professor A. M. Butleroff, the founder of the theory of structure of organic combinations, has played a great part in the development of organic chemistry in general, and high molecular compounds (and thus plastics) in particular.

The importance of the chemistry of high polymeric systems may be gauged from the fact that, since January, 1940, the editorship of the leading organ of German chemical thought, the " Journal für Praktische Chemie," has been entrusted to Professor Staudinger, whose recent works contributed so much to the advancement of the high polymeric chemistry.

This, naturally, has reflected on the general direction of the above journal, which, as has been pointed out by Staudinger in his introductory article,[169] will devote in the future special attention to the publication of works relating to the realm of high molecular compounds.

In this connection it is equally signifi-

cant to note that, in addition to its general title, the above-mentioned journal has on its front page also the subheading: "With Special Reference to Researches on High Polymeric Chemistry." The most interesting feature, which is forcing itself upon the attention of the scientific worker, is the trend in researches on high polymeric systems by approaching them from an electronic standpoint, as testified by records of Staudinger's school and others.

Molecular Complexes from the Electronic Point of View

All changes of matter are conditioned by ceaseless regroupings of the electrons. They take place in both stable and unstable structures of matter, the fundamental difference between the two types being characterized merely by the varying degree of ease of regrouping.

The changes occur with particular ease in non-polar molecules. In these the non-polar regroupings of the valent electrons take place in such a manner that the degrees of approach and the duration of attachment of the valent electrons belonging to neighbouring atoms are equal; i.e., the nature of motion of valent electrons in the non-polar molecules is such that, if at any one infinitesimally small period of time the valent electron approach one of the neighbouring atoms, then within the next period of the same duration they move away from a given atom and approach its partner.

By virtue of this motion, each atom of the non-polar molecule alternately carries the charge of the opposite sign, and, consequently, in the non-polar molecules each positive charge is replaced by an equivalent charge of the opposite sign.

Hence, owing to a continuous rebuilding of the electronic structure, the non-polar molecules are distinguished by latent polarity, and their atoms are non-ionized.

The constant regrouping of valent electrons in the polar molecules is carried out in such a way that the degrees of proximity and the duration of the attachment of the valent electrons of certain atoms ("acceptors" of electrons) are greater than those of other atoms (the "donors" of electrons). It is natural, therefore, that in the polar molecules this sequence of changes of the positive and the negative charges does not occur with the same facility as in the non-polar molecules; at the same time, the polar molecules have not that mobility of electronic structure and that ease of transformation from the patterns with one distribution of charges into patterns with the reverse distribution of charges.

In other words, while in non-polar molecules tautomeric regroupings of the valence electrons occur, causing their continuous reconstruction in the polar molecules, we are met with the phenomenon of braking of tautomeric regrouping of valence electrons, and, hence, with the displacement of the equilibria between the two polar tautomeric forms of the molecule in the direction of one of them.

As a consequence of this braking effect on the polar molecules, there arises the predominant distribution of charges, and their atoms acquire definitely pronounced ionic properties. Of course, the stronger the resistance to the tautomeric regroupings of valence electrons, the more stable becomes their electronic structure and the more difficult for it to effect the change of the charges of their atoms. And, accordingly, the stronger become their ionic characteristics.

Whence we see the connection between seemingly quite remote phenomena, such as the tautomerism and ionization.

Practical Sequel

The discovery of the connection between the phenomena of tautomerization and ionization indicates that the degree of ionization of a substance directly depends upon the mobility of its electronic structure and, consequently, upon the facility of the transformation of charges of its atoms. Thus, by varying the mobility of the electronic structure, we can alter not only the degree of ionization of the body, but also its polar nature.

The stabilization of the electronic structure of a molecule, on the one hand, impedes the transformation of the charges and leads to their relatively constant distribution in the atoms, and, on the other hand, increases the dissociation of the molecule.

Thus, the more stable the electronic structure of the molecule, the less is its constitutional strength. However, on the other hand, the more stable the electronic structure of the molecule, the more stable its valence bonds and, consequently, the weaker is their bonding ability. And, evidently, the less is the capacity of the molecule for additive reactions.

The stability of the valence bonds of the molecules is determined by the intensity of interaction between the valence electrons and the atomic nuclei.

In an atom each electron occupies a definite volume. The greater the degrees of the proximity and the attachment of the valence electrons in the atoms, the stronger the valence electrons will be attracted by the nuclei of these atoms.

It is the latter circumstance that causes the reduction of the distance between the valence electrons approaching the atom, and strengthens their interaction.

The interaction of the valence electrons in the molecules occurs with a varying intensity and, therefore, leads to the formation of electronic systems, the pairs of valence electrons (formed by the two nearest valence electrons) with different degrees of stability.

This leads us to the conclusion that between the molecules having doublets of valence electrons with the maximum strength, there exist all the degrees of the transition to the molecules with the free (non-doubleted) valence electrons.

Thus, the variation of the store of energy of the valence electrons, or the stability of the molecular valence bonds depends upon the intensity of interaction between the valence electrons.

Clearly, then, the stability of the valence bonds directly depends upon the mobility of the electronic structure of molecules.

In the molecules with a highly mobile electronic structure, i.e., in weakly ionized molecules, the electrons of valence bonds alternately approach the neighbouring atoms, and their degrees of the proximity and the interval of attachment to each of these atoms are very small.

Accordingly, in the weakly ionized molecules the interaction that occurs between the valence electrons and atomic nuclei of the low order of intensity, and, correspondingly, their valence electrons possess an adequate store of energy.

Whence it follows that in the weakly ionized molecules the valence bonds are of the inferior stability.

In the molecules with the stable electronic structure, i.e., in the highly ionized molecules, the degrees of the proximity and the interval of the attachment of the electrons of the valence bonds to one of the atoms is much greater than the other, and, therefore, the change of the charges of their atoms is strongly impeded. Thus, in the highly ionized molecules the interaction between the valence electrons and the atomic nuclei takes place with the great intensity, and the store of their energy is small.

This is why in highly ionized molecules the valence bonds are far more stable, and their bonding capacity is much lower than in the molecules weakly ionized. Otherwise put, the bonding power of the valence bonds of the molecules is the greater, the more mobile is their electronic structure, and the easier is effected the change of their atomic charges.

In the molecules with the double and multiple bonds, in general, the electrons of each valence bond, during their approach to the atoms, find themselves at different distances from their nuclei, and, consequently, interact with them with unequal intensities. This explains why in the molecules with double bonds the store of energy of one of the valence bonds is greater than that of the other, and, therefore, one of the bonds is more stable than the other.

The stability of the double and the multiple bonds, again, is directly dependent upon the mobility of the molecular elec-

tronic structure. In the molecules with a stable electronic architecture the store of energy of bonding forces is smaller than in the molecules with the mobile electronic structure.

It is natural, therefore, that the more stable is the electronic structure of the molecule, the more stable are all its valence bonds.

The foregoing shows that the more mobile the electronic structure of a molecule, the weaker the molecule is ionized and the less stable are its valence bonds. Hence it follows that the stronger the molecule is ionized the more stable are its valence bonds, and the smaller is their bonding capacity.

The substances with a highly mobile electronic structure have easily transformable charges of the atoms and, therefore, possess weakly expressed ionic properties.

In the weakly ionized bodies the valence bonds are of low stability, and, consequently, have a high bonding ability. By virtue of these properties, the substances with a highly mobile electronic structure, on the one hand, should display a small tendency for interactions, generally, especially for polymerization, and, on the other hand, if they do interact, must give stable combinations.

Indeed, as the works of Staudinger[170] have demonstrated, the slower is the rate of the polymerization of a substance, the more stable polymers it yields, and the higher is their molecular weight.

Whereas in polymers of non-ionized and weakly ionized molecules the electronic structure is highly mobile and the change of the charges of their atoms proceeds very freely, in polymers of ionized molecules the electronic structure is stable, and, therefore, their atoms possess relatively constant charges. Hence, the more ionized are the polymers of the molecules, the feebler is their ability for altering their electronic structure and, thus, the more constant, relatively, are the charges of their atoms.

This relative constancy of the electric charges imparts to the atoms a greater mobility and, at the same time, conditions their regular symmetrical arrangement in space.

From the above it follows the more stable is the electronic structure of the substance and the more constant, relatively, are its atomic charges, the more symmetrical is the spatial distribution of the atoms. It is natural, therefore, that the more stable is the electronic structure of a body, the stronger is its tendency for crystallization.

Crystallization, Fusibility and Solubility

If stabilization of the electronic structure of matter leads to the crystallization of a substance, the increase of the mobility of the electronic structure of a body, by disturbing the symmetry of the spatial arrangement of its atoms, prevents the substance crystallizing.

All the foregoing shows that the stronger the tendency of a body to alter its electronic structure, and the easier the changing of its atomic charges, the greater the difficulty of crystallization.

In bodies possessing a highly mobile electronic structure the valence bonds are of low stability, and, therefore, their bonding capacity is great. On this ground it is legitimate to infer that the more mobile the electronic structure of the substance, or the feebler the latter is ionized, the more difficult its crystallization, and, on the other hand, the higher must be the stability of its crystals.

Whence it follows that polymers of weakly ionized molecules should display a lower tendency for crystallization than the polymers of strongly ionized ones.

At the same time, the polymers of feebly ionized molecules should be more difficultly soluble and fusible than polymers of strongly ionized molecules.

(To be continued)

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